UNCLASSIFIED/UNLIMITED

DRG GRD

NORTH ATLANTIC TREATY ORGANIZATION

DEFENCE RESEARCH GROUP

1305-96

TECHNICAL REPORT
AC/243(LTSS)TR/44
Volume 1

LONG - TERM SCIENTIFIC STUDIES

LTSS/44 ON ENVIRONMENTAL TECHNOLOGIES FOR APPLICATION TO NATO MILITARY ASSETS AND BASES

VOLUME 1 : MAIN REPORT

Panel 1 on Long-Term Scientific Studies

UNCLASSIFIED/UNLIMITED

UNCLASSIFIED/UNLIMITED

REPORT DOCUMENTATION PAGE

1. Recipient's Reference:	2. Further Reference:	
3. Originator's Reference AC/243(LTSS)TR/44 Volume 1	4. Security Classification UNCLASSIFIED/UNLIMITED	
	5. Date: 23 September 96	6. Total Pages: 208

7. Title:

Long-Term Scientific Study/44 (LTSS/44): Environmental Technologies for Application to NATO Military Assets and Bases

8. Presented at:

Multinational Exercise at IDA, United States

9. Authors/Editors:

J. E. Tumarkin (US) Study Director; S. L. Clark (US), L. Coppet (France), J. L. Goasdoue (France), C. Grunert (Germany), A. L. C. Janssen (Netherlands), J. E. Larburu (Spain), G. Marshall (UK), K. Reimer (Canada), J. Rogers (Canada)

10. Author(s)/Editor(s) Address:	11. NATO Staff Point of Contact:
Institute for Defense Analyses 1801 N. Beauregard Street Alexandria, VA 22311-1772	Defence Research Section NATO Headquarters B-1110 Brussels Belgium (Not a Distribution Centre)

12. Distribution Statement:.

Approved for public release. Distribution of this document is unlimited, and is not controlled by NATO policies or security regulations.

Note: A separate supporting document entitled, "Technical Data and Information: Appendices to LTSS/44 Report", is for official use only. It should be announced and supplied only to NATO, Government Agencies of NATO nations and their bona fide contractors. Distribution to other recipients requires authorization by the head of the Defence Research Section.

13. Keywords/Descriptors:

Environment, Pollution Prevention, NATO Bases, NATO Ships, Contamination of Air, Water and Ground Water, Petroleum Pollution, Munitions Pollution, Surface Coatings, Solvents and Cleaners, Shipboard Wastes, Pesticides, Environmental Security, Environmental Compliance, Environmental Conservation, Safety, Occupational Health.

14. Abstract:

LTSS/44 studied 10 contaminant areas of interest to NATO's efforts to stop environmental pollution at the source. The study areas included: 1) Petroleum, Oils and Lubricants; 2) Munitions; 3) Fire Suppressants and 4) Refrigerants (Ozone Depleting Substances - ODS); 5) Solvents and Cleaners (Volatile Organic Compounds - VOC); 6) Organic and 7) Inorganic Surface Coatings; 8) Liquid Shipboard Wastes; 9) Solid Shipboard Wastes and 10) Pesticides. Each problem area was described in detail. The current situation, on-going research and recommended directions to accelerate the phase out or elimination of each contaminant (area) by substitution, process change and management improvement was described in detail. Finally, LTSS/44 recommended a way forward for the Defence Research Group to embrace further study of the means to eliminate and prevent contamination while minimizing the impact of compliance with environmental regulations, laws and international agreements on the NATO military mission.

UNCLASSIFIED/UNLIMITED

CONSEIL DE L'ATLANTIQUE NORD
NORTH ATLANTIC COUNCIL

UNCLASSIFIED/UNLIMITED

ORIGINAL: ENGLISH
23 September 1996

TECHNICAL REPORT
AC/243(LTSS)TR/44
Volume 1

DEFENCE RESEARCH GROUP

PANEL 1 ON LONG-TERM SCIENTIFIC STUDIES

Technical Report on Long-Term Scientific Study 44 on Environmental Technologies for Application to NATO Military Assets and Bases

Note by the Head of the Defence Research Section

1. This is the report by the Group of Experts who met at the Institute of Defence Analysis, Washington, United States, on 5-13 February 1996 during the Multinational Exercise (MNE) concluding the Long-Term Scientific Study (LTSS) on Environmental Technologies for Application to NATO Military Assets and Bases. Volume 2 (Appendices to LTSS/44 Report: Technical Data and Information) (NU) is being distributed separately.

2. The work of the Group at the MNE concentrated on the review and editing of the national contributions, under the leadership of the Study Director, Dr. Joel Tumarkin (US).

3. It should be emphasized that this report represents a consensus among the participants in the MNE who had no mandate to represent their nations or commands, but had been selected as individual experts in the field. Therefore, the report does not have to be officially endorsed by the nations or Military Authorities.

4. However, national and NATO authorities are invited to collect and send all comments to the Study Director, with a copy to the Defence Research Section as soon as they become available. All comments received will be assembled by the Study Director in a consolidated report to Panel 1, within one year after the publication of this LTSS report.

5. The Naval, Air and Army Armaments Groups are invited to draw the attention of their associated Panels and Groups to review this report and forward their consolidated comments to the Study Director with a copy to the Defence Research Section.

6. The Executive Summary (Yellow Pages) has been distributed under reference AC/243-N/474, dated 23 September 1996.

(Signed) Dr. K. GARDNER
Head, Defence Research Section

NATO,
1110 Brussels.

LONG-TERM SCIENTIFIC STUDY/44 (LTSS/44): ENVIRONMENTAL TECHNOLOGIES FOR APPLICATION TO NATO MILITARY ASSETS AND BASES

J. E. Tumarkin, *Project Leader*
S. L. Clark
L. Coppet
J. L. Goasdoue
C. Grunert
A. L. C. Janssen
J. E. Larburu
G. Marshall
K. Reimer
J. Rogers

ACKNOWLEDGMENTS

The Study Director of LTSS/44, Joel Tumarkin, wishes first to thank the members of LTSS/44 for their excellent work and dedication to the important subject of pollution prevention. The other members of LTSS/44 are: Susan Clark, Lucien Coppet, Jean-Louis Goasdoue, Christian Grunert, Anton Janssen, Jose Larburu, Greg Marshall, Kenneth Reimer and Jennifer Rogers. He also wishes to thank RAdm. Burnham (Mike) McCaffree (USN Ret.) and Mr. E. Thomas Morehouse who provided expert guidance on Ship Wastes and Ozone Depleting Substances respectively.

All the members of LTSS/44 wish to express their deepest gratitude to a number of people who made this report possible. Without their knowledge, experience and suggestions, this document—and the work of LTSS/44 generally—would not have been nearly so rich.

The first group of people we would especially like to thank are the subject-matter experts who attended the Multinational Exercise (MNE) for LTSS/44 in February 1996. They are: Craig Alig, Edward Ansell, Holmer Berthiaume, Joan Beshai, Rien Bossard, Rodrigue Boulay, Christopher Bowers, David Breslin, Dexter Bryce, Thomas Bush, Catharine Cyr, Alvin Day, Sue Dickout, Wilhelm Fleck, Wayne Fordham, Chuck Gawenis, Robert Goldberg, Carroll Herring, Eric Hofstede, David Honeyman, Paul Ihrke, Richard Kinzie, Larry Koss, James Reginald Lewis, Burnham McCaffree, Robert McKenna, Bruce Monahan, Tom Morehouse, Peter Mullenhard, Christoph Otten, Anna Palmisano, Michelle Pok, David F. Pulley, Anthony Rodriguez, Jim Rudroff, Thomas Sachar, Christian Simeit, Adrian Wilkinson and Robert Zanowicz.

In addition, we received valuable comments on the chapters from the following subject-matter experts who were unable to attend the MNE: Hugh Allen, Randy Allen, David Allison, Brian Ballew, Charles Beckman,Gilles Bellegarde, George Birkas, Gretchen Brockfeld, Gregory Brunner, M. Burberry, Lewis Cocks, Barry College, James Cornette, Daniel Daley, Robert Danahy, Patrick Daugherty, Ronald DeMarco, ICA Desvergnes, Kim Dix, Liliane Dubois-Hill, Jeffrey Duncan, Karen Durnford, Scott Edwards, Patrick Fink, Sharon Forrest, Carol Lee Giffin, Alonzo Gonzales, Luc Hains, Carl Handsy, Max Hartley, David Heiser, D. Hewitt, Chris Hitchin, Donald Hunt, Ernest Jenoiloinis, Robert Katz, Arlene Key, Thomas Landy, Christian Lecarpentier, Daniel Leclair, Francoise Leveque, D. Malone, Laura Maxwell, John McAndless, H. McDonald, R. Moore, J. Morinville, James Morris, Adelheid Muller, Cliff Myers, Alan Niedbalski, Jim Northcott, Daniel Pacquet, Susan Pecman, Andre Pelchat, Bryan Pellerin, Craig Pessetto, Julio Roldan, George Schmitt, Garnet Shearer, Chris J. E. Smith, Larry Sotsky, John Spencer, Jeffrey Stinson, John Stiver, Anthony Thornhill, Fred Tramontin, Mike Van Valkenburg, Joseph Wander, Gary Whitfield and Juergen Zander.

Within NATO, we would like to thank the following people for their support throughout all phases of LTSS/44: Keith Gardner, William Schultis, Anchangelo Simi, Dmitris Stamatopoulous and Ger Willemsen.

There are also several other people whose assistance has been valuable and supportive to the LTSS/44 study, including: Eon Claude, Francisco Coloma, Luis Diaz-Bedia, Anthony Downs, Ulrich Heym, Guido Lennertz, Guillermo Llamas-Ramos and John Stuart.

We are particularly grateful for the secretarial support provided by Rhonda Cook, Jackie Evans and Patty Hatter during the MNE and in the preparation of this document.

Finally, this project would not have been conceived or implemented without the intellectual and financial support of Sherri Wasserman-Goodman and Gary D. Vest in the US Department of Defence, Office of the Deputy Under Secretary for Environmental Security. It is therefore to the foresight of this and other environmental offices within the Ministries of Defence that we owe our deepest debt of gratitude.

TABLE OF CONTENTS

ANNEXES

TABLES

FIGURES

APPENDICES

See Technical Data and Information: Appendices to LTSS/44 Report.

EXECUTIVE SUMMARY

LONG-TERM SCIENTIFIC STUDY/44 AC/243(LTSS/44): ENVIRONMENTAL TECHNOLOGIES FOR APPLICATION TO NATO MILITARY ASSETS AND BASES

BACKGROUND AND INTRODUCTION

(i) In early 1994, NATO's heightened interest in the environmental aspects of military operations led to the acceptance of Terms of Reference for a Long-Term Scientific Study (LTSS/44) on Environmental Pollution Prevention to be conducted under the auspices of the Science and Technology Panel (Panel 1) of the Defence Research Group (DRG), Committee of National Armaments Directors (CNAD).

(ii) For many decades, the world's defence communities operated with little consideration given to the undesirable environmental effects caused by their activities. Although NATO environmental awareness has been raised significantly, it has been primarily through efforts to clean up the consequences of contamination from operations by their militaries. What is crucial for the environment today, and in the future, is to either completely eliminate or significantly reduce the sources of pollution, so that new contamination does not occur. This can be accomplished through the use of less environmentally harmful alternative materials, modifying manufacturing and assembly processes, and instituting management and logistics changes. NATO also supports environmental education for all members of the alliance and at all levels of rank. Only through education and increased awareness of environmental risk will the militaries of the world be enabled to truly practice pollution prevention and conservation of precious resources so vital to life on this planet.

THE FOCUS OF LTSS/44

(iii) LTSS/44 set four principal objectives for research:

- To understand the nature of contaminants, hazardous materials, and toxic wastes being emitted by ships and from military bases;
- To identify those technologies and strategies either in existence, under development, or planned for future research and development that aim to minimize or eliminate specified hazardous

emissions, materials, and waste from military operations;

- To identify areas for the potential application of those technologies and strategies to NATO's military environmental pollution concerns; and

- To determine areas in which future environmental research and development is required and is of particular concern to the NATO military alliance.

THE PARTICIPANTS AND STUDY AREAS

(iv) The study experts first identified a list of their nation's ten most pressing military-related environmental concerns, and later agreed to a consolidated list for the study. The study members then conducted in-depth research on these ten areas to serve as proof of concept for research into pollution prevention issues. The study areas and the lead nation for each are:

Contaminant Study Area		Lead Nation
1.	Petroleum, Oils and Lubricants (POLs)	France
2.	Munitions, Energetics, and Propellants	Germany
3./4.	Ozone Depleting Substances (ODSs) Fire Suppressants and Refrigerants	Netherlands
5.	Volatile Organic Compounds (VOCs) Solvents and Cleaners	Canada
6.	Inorganic Surface Coatings	US
7.	Organic Surface Coatings	UK
8.	Shipboard Liquid Waste	Spain
9	Shipboard Solid Waste	US
10.	Pesticides	UK

(v) For the purposes of the final working paper it was decided to combine topics 3 and 4 into one chapter entitled, *Ozone Depleting Substances*, topics 6 and 7 into one chapter entitled, *Surface Preparation and Coatings*, and topics 8 and 9 into one chapter entitled, *Shipboard Solid and Liquid Wastes*. The findings and conclusions drawn from the research are presented below and represent the current situation in the participating nations. The fairly wide range of sophistication in approach and technology represents to some extent the differences in national investments and budgets for environmental research and development.

DEFINING POLLUTION PREVENTION

(vi) Because NATO has not officially defined "pollution prevention," the LTSS/44 study adopted the following definition. It is hoped that this definition may become incorporated into NATO's lexicon on a more permanent basis.

Pollution prevention is defined as:

"The introduction of alternative materials, practices, processes, and energy sources that avoid, minimize, or eliminate the creation and introduction of pollutants and wastes into air, soil, and water. The focus of *pollution prevention* is to identify approaches that: first, reduce or eliminate contaminants at the source whenever possible; second, recycle that which cannot be eliminated; and third, treat and dispose of waste that cannot be eliminated as a last resort."

COOPERATION WITH OTHER NATO EFFORTS

(vii) To ensure that maximum benefits (leverage) would inure to LTSS/44 from other NATO environmental studies, the Study Director maintained close contact and liaison with the Committee on the Challenges of Modern Society (CCMS) and with the Naval National Armaments Group, Special Working Group 12 (SWG12). LTSS/44 requested and received approval from the Defence Research Group to establish contacts with the Partnership for Peace nations. In October 1995, LTSS/44 and SWG12 co-hosted a technical meeting with the PfP in The Hague. The central topics for discussion focused on environmentally sound ships for the 21st Century. The success of this first study outreach by the DRG was noted and should lead to further cooperative efforts with the Central European nations and newly independent states of the Former Soviet Union.

SUMMARY OF FINDINGS

(viii) The following sections summarize the important findings, conclusions and recommendations as developed by the LTSS/44 study members and by those experts who participated in either the technical review or the Multi-National Exercise.

STUDY CONCLUSIONS

(1) Policy. NATO has developed a high level of awareness regarding the necessity of the military forces to recognize and comply with national and international environmental regulations and laws. The NATO military supports broadly the concept of Environmental Security: environmental

compliance without sacrifice of the military mission within an acceptable economic framework.

(2) Education and Training. Through an educational and training process at all levels, NATO is determined to be proactive relative to environmental law. The NATO military must also be able to voice its positions at the time environmental legislation is drafted rather than at the compliance stage.

(3) Interdependence is required throughout the Alliance. NATO must leverage each member's resources during these times of shrinking budgets. A leveraged approach to research and development, eventually leading to the identification of alternative solutions to common, difficult environmental problems, must be based on a sharing of in-country R&D and program harmonization in order to avoid costly duplications. To this end, the NATO nations are committed to cooperative efforts within the alliance, with industry and with academia to solve mutually vexing problems.

(4) The Partnership for Peace (PfP) must be included in all environmental programs. Pollution Prevention activities must be extended throughout Europe. NATO should make every effort to maintain communication and share non-sensitive environmental information and findings with the Cooperation Partners.

SUMMARY OF CONTAMINANT STUDY AREAS

(ix) Specific recommendations for each Contaminant Study Area are found in the chapters that follow. A summary of the nature of the problem and the principal findings for each area is provided.

(x) The study team made no attempt to prioritize the findings or recommendations within the contaminant study areas or across the study areas. All study members did, however, agree to the recommendations listed at the end of this executive summary. It is hoped that subsequent studies and analyses may attempt to set priorities on a NATO-wide basis. It must be noted, however, that each national expert recognizes the need to confront contamination problems of local urgency and also to address those of international concern. The two needs may compete with each other given the constraints set by national resource allocations to environmental problems.

PETROLEUM, OILS, AND LUBRICANTS (POLS)

The Problem

(xi) Major oil by-products such as gasoline, heating oil, gas-oil mixtures and lubricants are highly polluting to the environment. They consist of polycyclic aromatic, naphtenic, paraffinic and olefinic hydrocarbon mixtures. They also contain small amounts of sulfur, benzene and, in certain cases, lead. Furthermore, additives with potentially unknown toxicological effects are occasionally found in these mixtures.

(xii) A great variety of fuels and lubricants are currently used by the NATO forces. In Annex C of STANAG 1135, no fewer than 14 fuels and 63 different lubricants were indexed. Annex B, assigns a NATO number code to each product, and in some cases a STANAG has been adopted as the standard product reference. Lubricants encompass an even greater variety of products due to their very specific uses.

(xiii) Industrial POL improvements are of vital interest to the NATO forces. It must be recognized, however, that NATO, while a significant customer, is not a dominant customer in the petroleum industry. Therefore, even though NATO may not be able to dictate changes to industrial POL specifications for day to day military uses, there are significant steps that can be taken by the NATO militaries to reduce pollution emanating from the use and handling of POLs.

The Findings

(xiv) Many technologies are currently available that can be employed to achieve significant degrees of pollution prevention for POLs. Additional studies are required to improve existing techniques and identify candidate applications where these technologies can be implemented.

(xv) The mandatory switch to unleaded gasoline and the wide adoption of vehicles equipped with catalytic exhaust systems are now demanding that refineries improve the technologies used to produce higher research octane number (RON) gasoline. New processes have been developed including paraffin isomerisation, alkylation, and oligomerisation or etherification of olefins. Benign fuel additives are now highly favored to enhance octane numbers while reducing harmful emissions.

(xvi) NATO equipment which incorporates internal combustion engines (IC Engines) should attempt to consume unleaded fuels whenever possible and to incorporate catalytic converters for most non-diesel military vehicles and trucks. Training must be accelerated in the safe and careful handling of POL in order to avoid spills and fuming.

Improved storage vessels and techniques can also reduce pollution arising from inadvertent POL leakage.

(xvii) NATO military forces can support the industrial development of cleaner and more efficient POLs. Military applications must consider potential uses for alternative gas-oils, potentially based on conversion of natural gas or vegetable oils, to further reduce pollution from internal combustion engines. This research noted that alternative fuels may have some use in a non-operational environment, but their use in operational theaters may contradict the NATO Single Fuel Concept. Alternate fuels may also exhibit limitations when required to operate across a wide range of ambient field temperatures. A number of biodegradable lubricants now exist in the commercial marketplace and have also found some limited applications in the military environment. Alternate fuels represent a smaller market share at this time and may therefore be more responsive to NATO requirements than is the broader conventional fuels market.

MUNITIONS, PROPELLANTS AND ENERGETICS

The Problem

(xviii) Environmental awareness in the area of military munitions, propellants and energetics is at a low level. Operational requirements, both for training and peacetime operations, have not placed a high priority on environmental security considerations. Two separate issues were addressed regarding pyrotechnics: 1) weapons training and use; and, 2) demilitarization and recycling of excess and obsolete weapons.

(xix) Little thought has been given to the environmental impact of destructive weapons. Munitions, propellants and energetics exhibit pollution and environmental contamination characteristics that are specified at the earliest stages of development and then persist throughout the life of the weapons.

(xx) If pollution prevention is to be achieved, environmental issues must be considered at the very first stages of weapons design and development. An understanding of the environmental impact that occurs over the course of the life cycle of a weapon should enable industry to provide more environmentally acceptable munitions.

(xxi) Pollution prevention problems exist at four stages in the life cycle, namely: design, manufacture, use and recycling (demil). Efforts in research and development should therefore be concentrated on design, manufacture and recycling.

(xxii) Current disposal and recycling technologies for pyrotechnics may not be environmentally acceptable. The pressure on the NATO nations to demilitarize and recycle existing stockpiles and obsolete inventories of munitions is high.

(xxiii) This study has been unable to identify significant R&D that could result in the design of alternative weapons and munitions which would be less environmentally damaging during training and exercises.

The Findings

(xxiv) Environmental awareness needs to be increased among the NATO military forces with respect to munitions, propellants and energetics. Operational requirements both for training and peacetime operations should be reviewed, taking into account environmental security considerations. As a result, operational and training procedures should be reexamined and modified, where feasible, to reflect growing international environmental concerns.

(xxv) Environmental issues must be considered at the initial stages of development, i.e., concept and design, in order to produce more environmentally acceptable munitions. First steps in this direction are now being taken by NATO and its suppliers.

(xxvi) Efforts in research and development should concentrate on production and reuse. Additional R&D and changes in operational guidance are needed to provide environmentally acceptable munitions and components.

(xxvii) The demilitarization (demil) phase should analyze environmental cost benefit considerations for alternative destruction/recycling approaches.

OZONE DEPLETING SUBSTANCES (REFRIGERANTS AND FIRE SUPPRESSANTS)

The Problem

(xxviii) For many years the military has used ozone depleting substances (ODS) in refrigeration and air conditioning systems, fire suppression systems, and in maintenance operations. The Vienna Convention for the Protection of the Ozone Layer accepted that the depletion of the ozone layer by these chemicals could harm the environment and human health. This led to the Montreal Protocol Agreement of 1987, which has virtually eliminated the world-wide production of fully halogenated chlorofluorocarbons and halons.

(xxix) Alternatives for many military applications have been identified, proven and implemented. However, some existing NATO military systems such as tactical vehicles, aircraft and ships will continue to be dependent on ozone-depleting substances for the foreseeable future. Further research is needed to find alternatives for these remaining uses. Efficiency, weight, volume, cost, toxicity and partial pressure problems of substitutes

are presenting the research community with a serious problem in the search for ODS substitutes.

(xxx) To ensure the continued availability of certain chlorofluorocarbons (CFCs) and halons for mission critical applications, and in the absence of newly manufactured supplies, many nations in NATO, and their Ministries (or Departments) of National Defence, have established *CFC banks* as repositories for surplus stocks.

The Findings

(xxxi) It has been determined that alternatives for most high use applications of ODS have now been developed and are being implemented. Practical alternatives for several weapons platform applications have not yet been identified; however, supplies of recycled ODS appear to be adequate to service mission critical military needs at this time and for the foreseeable future.

(xxxii) Differing national rules regarding import/export and the end uses of recycled ODS among the North Atlantic alliance nations have the potential to impact planned exercises and the peace-keeping operations of NATO militaries when operating on foreign soil.

(xxxiii) Further research is needed into the understanding of fire and fire suppression chemistry and into promising new technologies for fire suppression and fire extinguishing.

(xxxiv) Further research is needed into alternative new refrigeration technologies and improvements, including approaches such as thermoelectric, evaporative cooling and desiccant cooling.

(xxxv) NATO should consider qualified military representation and membership on the United Nations Technical Options Committees to ensure that the Montreal Protocol Parties consider unique military needs, including the need to allow continued use of recycled ODS on mission critical systems.

VOLATILE ORGANIC COMPOUNDS (VOCS)
SOLVENTS AND CLEANERS

The Problem

(xxxvi) Many solvents and cleaners in use worldwide are toxic or contribute to the formation of tropospheric ozone or stratospheric ozone destruction. There is a need to replace all of these classes of compounds with less harmful alternatives. Most solvent

cleaning applications, even apparently similar ones, have unique characteristics that prevent implementation of across-the-board replacements to CFC-113 and 1,1,1-trichloroethane, the ODS solvents most commonly used due to their versatility.

(xxxvii) Pollution prevention for solvents used in cleaning applications can include a process change that reduces or eliminates the cleaning requirement, or that makes the delivery or recovery of the solvent more efficient, resulting in a decreased use of solvent. Substitution of a different kind of solvent is another form of pollution prevention and may also involve a process change. Changes in management practices, such as determining how clean the part really needs to be, storing parts in such a way that they do not need to be cleaned repeatedly, and implementing the pharmacy concept of issuing limited quantities for specific needs are also effective ways to reduce solvent usage.

(xxxviii) Six general types of cleaning were examined. These were chosen based on their high volume use or the difficulty of finding alternatives, and are: wipe cleaning, precision cleaning, cold cleaning, vapor degreasing, cleaning of electronic components and cleaning of oxygen systems. Many of these cleaning systems are candidates for replacement with aqueous, semi-aqueous or benign hydrocarbon cleaners.

The Findings

(xxxix) While few industries have as many applications and different types of parts to clean as the military, there have been technical solutions identified for eliminating VOCs from most cleaning applications. Each application has unique characteristics that prevent implementation of across-the-board solutions; however, solutions do exist for most applications.

(xxxx) This study could not reach agreement either on the requirement for cleaning or on the cleaning process to be used for oxygen systems.

(xxxxi) A requirement exists to eliminate those toxic solvents used for cleaning in confined spaces. It is also necessary to replace emulsifying degreasers for bilge and ship tank cleaning.

(xxxxii) A NATO-wide management review of cleaning procedures is necessary. LTSS/44's research has determined that some cleaning operations are not necessary and in others the degree of cleaning is excessive. Requirements for cleaning need to be examined and rationalized. More information is needed to determine the health and safety aspects of the various cleaning technologies.

SURFACE PREPARATION AND COATINGS

The Problem

(xxxxiii) The processes that are used to apply organic and inorganic surface coatings to military equipment produce a significant and negative environmental impact. The life-cycle of military equipment and weapons platforms repeat the following coating history: surface preparation; coating application; coating removal; and eventually, reapplication of a new coating. Each sequence involves the use and release of hazards in the form of heavy metals and VOCs into the air, ground and water.

(xxxxiv) In order to comply with both national legislation and international agreements, the NATO alliance members must now take appropriate action to prevent release of these hazards into the environment, and must do so without significant sacrifice to the military mission. This study identified the environmental hazards created by heavy metals and VOCs emanating from surface preparation, coating systems and coating removal methods.

The Findings

(xxxxv) NATO must recognize that much research and development work remains to be completed in order to minimize the negative environmental impact arising from both inorganic and organic surface preparation and coatings activities.

(xxxxvi) The efficiency of coatings transfer processes in military operations are in need of substantial improvement. There is a pressing need for high efficiency paint spray equipment, longer lived coatings, primerless coatings for aircraft, reduced toxicity, narrow targeted, anti-fouling marine coatings, and cost-effective, non-chemical methods for coatings removal.

(xxxxvii) Specialized military needs include: non-chromated corrosion inhibiting coatings for aircraft; low VOC coatings for camouflage, concealment and deception (CCD); minimization of heavy metal disposal from plating processes; reduction in the use of chromium, cadmium, copper and lead; and the development of a clean blast medium for paint removal.

SHIPBOARD SOLID AND LIQUID WASTES

The Problem

(xxxxviii) The shipboard waste stream is a source of pollution in the world's bodies of waters. While the NATO navies constitute a very small fraction of the total

population of ocean-going vessels, NATO is increasingly determined to reduce the potentially negative environmental impact of naval operations.

(xxxxix) Recognizing the potential threats to the environment caused by both solid and liquid wastes, international agreements on the reduction or elimination of shipboard waste streams have been implemented. The International Convention for the Prevention of Pollution from Ships (MARPOL), approved in 1973 and amended in 1978 by the International Maritime Organization (IMO), imposed significant restrictions on solid waste disposal by ships at sea in its Annex V; in turn, MARPOL's Annex I and its pending Annex IV impose significant restrictions on liquid waste disposal. Furthermore, MARPOL specifies general restrictions applicable throughout the world's oceans and seas (beyond territorial waters), as well as more rigid restrictions pertaining to special areas. At the present time, military vessels are exempted from complying with MARPOL provisions, although they are expected (and encouraged) to comply to the maximum extent possible. The NATO naval forces have voluntarily agreed to comply with MARPOL as a sound public policy decision and in order to be able to sail and conduct operations wherever necessary if and when MARPOL compliance becomes mandatory.

The Findings

(xxxxx) Present shipboard technology offers acceptable environmental protection in the short run. However, the goal of the scientific environmental community and ship designers must be to investigate future technologies that will be able to prevent pollution of the seas to the maximum extent possible without ignoring operational capabilities, space and energy constraints, and economic considerations.

(xxxxxi) Pollution prevention and naval waste abatement technologies will vary by country and by ship type, size, mission, time at sea and crew size. The selection of the appropriate solution(s) is often a political decision, but this decision must be based on the best available scientific analysis of the full range of costs and benefits for each option.

(xxxxxii) The use of commercial grade equivalent equipment is a viable alternative for some navies and for certain types of ships. Specifically, these commercial options are more appropriate for ships whose mission duration and logistics lines of support are not as long as those envisioned for US Navy ships.

(xxxxxiii) New-design ships will have many more environmental technology options available to them than existing ships. Backfitting existing ships with new technologies is, as a rule, prohibitively expensive and unrealistic. When assessing individual technologies, new design or backfit, compatibility with the overall ship design is always an important consideration.

PESTICIDES

The Problem

(xxxxxiv) A number of NATO members have to comply with national legislation relating to pesticides used for protecting personnel from disease vectors, and equipment and buildings from pest damage. These countries are working towards Integrated Pest Management (IPM) programs which aim to ensure that pesticide use is more sustainable and to see if cost savings can be obtained.

(xxxxxv) In response to national legislation, the US and Canada are developing IPM programs to make their use of pesticides more sustainable. The UK and Germany are also working closely with pesticide authorities to control their use of the materials. The costs of new IPM working methods, and the benefits of reduced pesticide use and liabilities now need to be established. Greater efforts are required to increase the understanding of, and training for, the NATO forces in the uses and benefits of IPM.

The Findings

(xxxxxvi) NATO STANAG 2048 is due for revision and should be made to shift its emphasis from chemical methods to IPM methods. Collaboration with the NATO CCMS study team on Environmental Management Systems is advised in order to establish feasibility of the IPM approach in assisting the development of other environmental management system elements.

(xxxxxvii) NATO members are seeking to eliminate the use of organochlorine and organobromine pesticides. NATO should monitor current research ongoing in Europe that may now lead to an acceptable alternative to pentachlorephenol for rot-proofing natural fabrics. This is particularly important for parachute and other restraint harnesses.

(xxxxxviii) NATO should support the development of Integrated Pest Management training programs to assist alliance and PfP members in adopting more sustainable approaches to pest control.

RECOMMENDATIONS

(xxxxxix) Long Term Scientific Study/44 produced the following three recommendations, which are intended to offer NATO a plan for positive action when dealing with environmental issues of concern to their military forces:

(1) Establish a SPECIAL GROUP OF EXPERTS (SGE) or an EXPLORATORY TEAM to identify and prioritize Environmental

Research, Development, Test and Engineering projects necessary to ensure that the NATO Military Forces are able to operate as needed without coming into direct conflict with existing or proposed regulations or agreements. Issues addressed may include restoration, pollution prevention, conservation, compliance, alternative energy, emergency response and toxic release. Media of interest will include air, water and soils.

(2) Establish a STUDY GROUP (under the auspices of the SGE) to compile a compendium of international and national environmental laws and regulations that directly affect the NATO military mission. Annotate each law or regulation with a potential environmental security impact statement. Clearly identify those regulations that are or will be the most difficult for NATO compliance.

(3) Establish a STUDY GROUP (under the auspices of the SGE) to recommend a computerized Technical Environmental Data Exchange for use by the DRG and the Alliance Nations.

CONTENTS OF THE REPORT

(xxxxxx) The Unclassified/Unlimited Distribution report that follows consists of an Introduction to the study and seven (7) chapters, each of which summarizes the research in one contaminant area: 1. Petroleum, Oil and Lubricants; 2. Munitions, Propellants and Energetics; 3. Ozone Depleting Substances; 4. Volatile Organic Compounds - Solvents and Cleaners; 5. Surface Coatings; 6. Shipboard Solid and Liquid Wastes, and 7. Pesticides. An appendix containing background, technical and other supporting data and materials is bound separately and, at the request of the study members, is classified NATO UNCLASSIFIED.

(This page is intentionally blank)

OUTLINE OF CHAPTERS

Paragraph No.

APPENDICES

See Technical Data and Information: Appendices to LTSS/44 Report.

CHAPTER 1

INTRODUCTION

1.1 THE EVOLUTION OF LONG-TERM SCIENTIFIC STUDY/44: ENVIRONMENTAL TECHNOLOGIES FOR APPLICATION TO NATO MILITARY ASSETS AND BASES

1. In early 1994, NATO's heightened interest in the environmental aspects of military operations led to the acceptance of Terms of Reference for a Long-Term Scientific Study (LTSS/44) to be conducted under the auspices of the Science and Technology Panel (Panel 1) of the Defence Research Group (DRG), Committee of National Armaments Directors (CNAD). At the request of the NATO Naval National Armaments Group (NNAG), and on behalf of their Special Working Group 12 (SWG/12), LTSS/44 agreed to include ship wastes as one pollution prevention topic addressed in this study. Recognizing that the NATO Committee on the Challenges of Modern Society (CCMS), Office of the Assistant Secretary General for Scientific and Environmental Affairs, has conducted many Pilot Studies on the Environment over the last 20 years, close liaison has also been maintained between the LTSS/44 Study and the CCMS.

2. Panel 1 of the Defence Research Group has as its mission to conduct a variety of scientific studies as may be agreed to by the membership and sanctioned by the Defence Research Group of the CNAD; the purpose of these studies is two-fold. First, they are to provide NATO and national authorities with an assessment of the progress that science and technology can be expected to achieve over the next 15 years, and of the impact this progress may have on the military sector. Second, LTSSs must provide research planners with recommendations for both national and multinational research programs and facilities.

3. For many decades, the world's defence communities operated with little consideration given to the undesirable environmental effects caused by their activities. Although NATO environmental awareness has been raised significantly, it has been primarily through efforts to cleanup the consequences of earlier contamination by their militaries. What is crucial for the environment today, and in the future, is to either completely eliminate or significantly reduce the sources of pollution, so that new contamination does not occur. This can be accomplished either through using less environmentally harmful alternative materials, modifying manufacturing and assembly processes, or instituting management and logistics changes.

1.2 THE FOCUS OF LTSS/44

4. LTSS/44 set four principal objectives for research:

A. To understand the nature of contaminants, hazardous materials, and toxic wastes being emitted by ships and from military bases;

B. To identify those technologies and strategies either in existence, under development, or planned for future research and development that aim to minimize or eliminate specified hazardous emissions, materials, and waste from military operations;

C. To evaluate the applicability of those technologies and strategies to NATO's military environmental pollution concerns; and

D. To determine areas in which future environmental research and development is required and is of particular concern to the NATO military alliance.

5. The following participating nations first identified, and later agreed to, a list of their ten most pressing military-related environmental concerns: Canada, France, Germany, Greece, Netherlands, Spain, United Kingdom, and United States. The national experts then conducted in-depth research on these ten areas to serve as proof of concept. These areas and the lead nation for each are:

Contaminant Study Area		Lead Nation
1.	Petroleum, Oils and Lubricants (POLs)	France
2.	Munitions, Energetics, and Propellants	Germany
3./4.	Ozone Depleting Substances (ODSs) Fire Suppressants and Refrigerants	Netherlands
5.	Volatile Organic Compounds (VOCs) Solvents and Cleaners	Canada
6.	Inorganic Surface Coatings	US
7.	Organic Surface Coatings	UK
8.	Shipboard Liquid Waste	Spain
9.	Shipboard Solid Waste	US
10.	Pesticides	UK

6. For the purposes of the final study it was decided to combine topics 3 and 4 into one chapter entitled, *Ozone Depleting Substances*, topics 6 and 7 into one chapter entitled, *Surface Preparation and Coatings*, and topics 8 and 9 into one chapter entitled, *Shipboard Solid and Liquid Wastes*.

1.3 DEFINING POLLUTION PREVENTION

7. Because there was no commonly used definition of "pollution prevention," LTSS/44 study members adopted a definition to be used in this study. It is hoped that this definition may become incorporated into NATO's lexicon on a more permanent basis.

> Pollution prevention is defined as:
>
> "The introduction of alternative materials, practices, processes, and energy sources that avoid, minimize, or eliminate the creation and introduction of pollutants and wastes into air, soil, and water. The focus of *pollution prevention* is to identify approaches that: first, reduce or eliminate at the source whenever possible; second, recycle that which cannot be eliminated; and third, treat and dispose of waste that cannot be eliminated as a last resort."

8. Thus, pollution prevention can be accomplished in a variety of ways. New technologies can be developed that either use less harmful materials or perform their job in a more environmentally friendly way (e.g., reducing the volume of the waste stream). Often, pollution can be reduced simply through the adoption of improved management and logistics techniques. For example, by keeping hazardous materials under better inventory control, less of the material is issued to the user [i.e., the user receives only what is needed to do the job rather than a full container of the hazardous material (pharmacy concept)], less of the hazardous materials become subject to later cleanup, and reduced quantities of the unused hazardous material are scrapped for short shelf life. These relatively simple efforts can save appreciable money in the form of hazardous materials purchases and disposal costs. In short, the key to pollution prevention in the military is hazard minimization and avoidance. While we will never be able to eliminate completely the use of all war fighting materials that are harmful in some way to the environment, the ability to eliminate the most harmful ones and to implement more efficient methods in their use or application will contribute significantly to a better and safer environment for all nations and peoples.

1.4 THE PROCESS OF LTSS/44'S WORK

9. In order to assemble the study's information, each member of the study group was tasked with identifying work being done in his nation pertaining to the ten selected contaminant areas. For each technology, process change, logistics or management change identified, a data information sheet was completed. The same format was used on all the information sheets, namely:

- description of the problem;
- description of the possible solution;
- characterization of the type of technology (alternative materials, process change, logistics or management change);
- status of the technology (whether it is available now or, if not, whether it would be available in the mid- or long-term);
- results achieved, if the technology is at some level of demonstration evaluation (demval);
- anticipated problems, either in further developing the technology or in making it operational (including such issues as investment cost, operating cost, capital/labor ratio, whether it creates another contaminant stream, whether there are possible regulatory impediments to implementing it); and
- additional items, such as the in-country point of contact to obtain additional information.

10. After these data were collected, each national representative then passed the relevant information to the member who was acting as the lead for that particular contaminant area. Thus, all countries who gathered information about pesticides provided it to the UK representative. The lead member for a given contaminant area then had the responsibility for reviewing all the inputs received from the nations and assembling them into a consolidated draft chapter.

11. Recognizing the importance of uniformity when reporting information, the LTSS/44 study members also agreed to a common format for the chapters analyzing the contaminant areas. They further agreed that, for this report, several of the contaminant areas would be combined into integrated chapters. The resulting seven

chapters, as noted above, are: petroleum, oils and lubricants (POL); munitions, energetics, and propellants; fire suppressants and refrigerants; volatile organic solvents and cleaners (VOCs); surface coatings; shipboard waste; and pesticides. These chapters, in fact, make up the majority of this report.

12. Each chapter begins by defining the *scope and nature* of the problem caused by the particular contaminant. Next, it addresses the *implications for the military mission* (how new technologies and strategies may affect a military's capabilities and readiness, and also how non-compliance with environmental regulations will affect a military's ability to operate in certain regions, i.e., Environmental Security). The third component is a summary of the pollution prevention technologies and approaches that the nations have identified. Areas for future research relating to the specific area of contamination are identified. It should also be noted that in the conclusions and recommendations portion of this report, possible areas for future research are highlighted. Finally, recommendations are made to Panel 1 and the Defence Research Group as to the future direction scientific environmental studies might take, and the nature of the military impact expected.

1.5 THE CONNECTION BETWEEN ENVIRONMENT AND MILITARY MISSIONS

13. There is an increasing appreciation about the connection between meeting both the environmental requirements and the readiness for the military mission. Meeting environmental requirements can have varying effects on the NATO military's ability to operate.

14. On the negative side, in many cases, the alternatives that are identified for less environmentally harmful materials and processes are more labor-intensive and may require more training for the personnel tasked with performing the mission. Thus, either manpower must be taken away from other tasks or more manpower must be added to the complement, a difficult solution in times of decreasing military budgets and forces. Other alternatives can require more energy (or are less efficient) than processes currently in use. This means that energy sources may have to be diverted from other military tasks and budgets in order to comply with environmental requirements. In still other cases, new technologies while environmentally sound, may alter the noise or infrared signature of stealth systems and thereby jeopardize the military mission. Clearly, military readiness and combat effectiveness can be impeded by having to comply with some environmental regulations. As a result, the requirements of the military sector must be considered by all environmental regulatory bodies and policy makers.

15. On the positive side, compliance with environmental regulations will give the militaries the flexibility they need in order to operate in a variety of circumstances and locations. Most notably, if naval vessels meet MARPOL "no discharge" requirements in the Special Areas,[1] they will be able to operate during peacetime in all areas without restriction (caused by environmental regulations). The navies will then reduce the risk of not being able to fulfill essential mission tasks. Reevaluation of military processes and technologies can lead to cost savings and efficiencies. Furthermore, the need to search for more environmentally acceptable alternatives can result in the selection of improved technologies that may lead to increased performance.

1.6 ENVIRONMENTAL CONSIDERATIONS AND THE ACQUISITION PROCESS

16. An important component to more sound environmental practices is the development of a better understanding of where to insert environmental considerations in military practices. The world's militaries (and civilian authorities) have already learned that inserting them at the clean-up stage is a very costly and inefficient option. As this study shows, trying to eliminate (or reduce) pollution at the source is a much more effective approach.

17. A difficult decision within the context of inserting environmental considerations at the "source," however, is a determination of the most effective and efficient points for doing so. Clearly, the earlier in the life cycle of a process, the better. Thus, it is better to design an aircraft, a ship or a battle tank with environmental compliance technologies and strategies taken into account, rather than trying to retrofit or backfit the weapon to comply. It would be extremely valuable for the NATO nations to identify at which stages of the acquisition process the insertion of environmental considerations is most appropriate, expedient and cost-effective. Ongoing research in the United States points to Milestone Zero or One (6.1 or 6.2 in the research and development process).

1.7 ADDITIONAL INFORMATION IN THE REPORT

18. In addition to the major substantive portions of this report, represented by the chapters dedicated to the contaminant areas and the conclusions and recommendations, other information contained in this report should also be highlighted. The document, Technical Data and Information: Appendices to LTSS/44 Report

---

[1] See Chapter 7 on shipboard waste for more detail.

(NATO UNCLASSIFIED), contains technical appendices to support this report, including the completed data collection forms for the areas under review for use by NATO as well as other technical information. These forms provide detailed information about the specific technology, process change or management-logistics change being implemented (or at least explored) by some of the alliance nations. Most also mention a point of contact for this work who could be contacted for more detailed discussions by readers of this report.

19. Another important contribution of LTSS/44 is the assembly of information for use by NATO about national and international data sources, databases and studies on relevant environmental issues. Annex III contains a list of these sources.

1.8 PARTICIPATION IN LTSS/44 AND LTSS/44'S INTERACTION WITH OTHER NATO EFFORTS

20. As with all NATO studies, participation by the nations was purely voluntary. The study group was led by a representative from the United States. The other six countries who participated in every aspect of the study (assembling national information, drafting chapters on the contaminant areas, and participating actively in the study meetings) are: Canada, France, Germany, the Netherlands, Spain, and United Kingdom. Several other NATO nations expressed interest in the study, occasionally attended meetings, and were sent all relevant LTSS/44 documents.

21. Every effort was made during the conduct of LTSS/44 to integrate its work with other environmental undertakings in NATO, notably to leverage any possible benefits. As already discussed, the CCMS has been involved for many years in environmental issues. Its pilot studies include work on anti-fouling paints, aircraft noise, cross-border pollution, and the environmental aspects of reusing former military lands. In addition, two other NATO groups merit mention. Under the NNAG, SWG/12 has been focused on the changing international and national environmental regulations affecting naval operations and on identifying elements necessary for the environmentally sound ship of the 21st century. Under the NATO Industrial Advisors Group (NIAG), Special Group 50 is conducting a Pre-Feasibility Study on Environmentally Sound Ships. It is assessing the applicability, affordability and availability of technologies for creating environmentally sound ships from an industry perspective. All three groups have held joint meetings and have shared information as warranted.

22. Finally, it should be noted that on several occasions, the work of LTSS/44 was discussed with the Cooperation Partner (Partnership for Peace) nations. While many of these nations expressed an interest in the work of this study, they also suggested that their most immediate environmental problems are to clean up past

contamination. Such priority is, of course, also mirrored in the Western nations, but it is hoped that this study, along with other pollution prevention efforts, will foster a deeper understanding among politicians, military leaders and the public at large about the need for investing more—by all of our nations—in pollution prevention strategies. As this approach becomes more widely adopted, the need for site restoration financing will be reduced appreciably.

CHAPTER 2

PETROLEUM, OILS, AND LUBRICANTS

2.1 INTRODUCTION

23. Hydrocarbon pollution emanating from petroleum, oils and lubricants (POLs) is a global problem, and is not confined to the military alone. The most frequently reported contaminant groups at military cleanup sites are identical to commercial sites. The military is a very large and identifiable consumer: in the United States, 15 percent of the 1,114 Army sites, 38 percent of the 995 Navy sites and 43 percent of the Air Force sites have some environmental problems with POLs.[2] The military consequently has a significant interest in, and responsibility for, POL pollution prevention activities. However, the global market for petroleum products, both raw and refined, approaches the economists' model of pure competition where no one buyer can exert a significant influence over price or product. It is not likely, therefore, that the NATO militaries can impose their environmental desires on a world market commodity. The petroleum industry must take the lead to research, develop and ultimately produce refined products that burn more cleanly and have fewer negative effects on the environment. Engine designers and manufacturers will also be necessary partners in any development effort. Within this context, the NATO military forces should behave in a proactive role to ensure that their technical opinions are considered in any emerging legislation that will attempt to control pollution emanating from the combustion of hydrocarbons. The NATO forces can also take immediate preventive actions to stop the inadvertent dumping, spillage or leakage of POLs into the ground and water. It is also possible to replace highly toxic contaminants with less toxic formulations.

24. Major refined oil products such as gasoline, heating oil, gas-oil mixtures and lubricants are highly polluting to the environment. They consist of polycyclic aromatic, naphtalenic, paraffinic and olefinic hydrocarbon mixtures. They also contain small amounts of sulfur, benzene and, in certain cases, lead. Furthermore, additives of various chemistry (to lower the freezing point or raise the flash point for example) are occasionally found in these mixtures and may add to the toxicological effects of the end product.

25. A great variety of fuels and lubricants are currently used by the NATO forces. Indeed, in Annex C of STANAG 1135, not less than 14 fuels and 63 different lubricants were indexed. According to Annex B, a NATO number code has been assigned to each product. In some cases, a STANAG has even been adopted as the standard reference. Concerning fuels, the main reference standards describing specific fuel types are:

---

2 Report of the Defence Science Board Task Force on Environmental Security, 22 April 1995.

F-34 and F-44 for the Air Forces; F-76 for Naval forces; and F-46, F-54 and F-65 for Army land forces.

26. Lubricants encompass a greater variety of products due to their very specific uses. The key references to product standards are: O-190 and O-192 for non-corrosive lubricants; O-226 and O-228 for gearing lubricants; O-237 and O-238 for diesel engine lubricants; and O-278 for marine diesel engines.

27. POL contamination is generally visible in air, as smog, and in water as an oily slick or as a raw petroleum product when it reaches the shoreline. POL spills have attracted worldwide attention in recent years as coastal areas have been dealt devastating blows from open ocean spills, e.g., Prince William Sound, Alaska, and the coast of South Wales in the British Isles. POLs dumped on the water surface will spread rapidly before being evaporated, dissolved, emulsified, photo-oxidized or microbially biodegraded.

2.2 ELEMENTS OF THE POL PROBLEMS

2.2.1 Toxicity on Man

28. In general, short-term exposure to hydrocarbons will not pose a direct threat to humans. However, long-term, low-level exposure to oil, or its byproducts, can affect human health. Polycyclic aromatic hydrocarbons (PAHs), contained within petroleum products, and also produced as a result of combustion, are known to be carcinogenic. The effect of exhaust emissions on human health is well understood and has been well documented. Hydrocarbon contamination of water supplies from spills or leaking underground or above-ground storage tanks will also cause both short- and long-term health problems to all forms of life.

2.2.2 Other Toxicological Considerations

29. In general, the toxicological impact on wildlife is similar to those effects on man as described above. Aquatic ecosystems are at particular risk as high viscosity hydrocarbons react with dissolved oxygen leading to the suffocation of living organisms. Fish, mollusks and other vertebrate and invertebrate life forms (and their predators) are significantly affected by hydrocarbon pollution. The end result then poses a threat to life to man and to those land and sea animals who are potential consumers of those organisms.

2.2.3 Accepted Limit Values (ALV)

30. There are no international regulations concerning acceptable levels of hydrocarbon pollution. However, many nations have limits for acceptable amounts of hydrocarbon in open water, in drinking water and as an air emission. In addition, there are

differing national, provincial (state), and local jurisdictional limits for the release of hydrocarbons from industrial processes.

31. In Europe, ALVs are determined by regulators that take into account the contaminant source and water flow data for the affected rivers where dumping or spills occur. For businesses subject to environment protection legislation, ALVs are expressed in allowable daily discharges (m^3/day).

2.2.4 Origins of Hydrocarbon Pollution

32. Hydrocarbon (POL) pollution can originate from:

A. Leaking tanks or pipelines;

B. An explosion;

C. Accidental dumping or spillage of an oily waste;

D. Careless disposal from everyday uses, including automotive repair;

E. Improperly sealed engines;

F. Aircraft fuel dumping; and

G. Leaching from waste/dump sites.

33. Many emissions originate from industrial smokestack waste and automotive and marine vehicle exhausts. Much of this returns to earth in the form of acid rainfall. These emissions are estimated to be 9 million tons per year.

34. It is interesting to note that in France, annual hydrocarbon pollution, including oils and fuels, has been estimated at 1 ton of hydrocarbons spilled per highway kilometer. This pollution is further harvested by rainfalls and eventually ends up in rivers, the sea or in underground waters.

35. In addition to the obvious problems of free fuel seeping into ground water and into open bodies of water, on occasion, the presence of fuel products in the vicinity of sewage pipes can lead to their contamination. Hydrocarbon (HC) infiltrations have been detected in sewage because of the high permeability rates of ordinary concrete piping to hydrocarbons. Non water-soluble HCs may prevent complete bio-degradation of sewage at the treatment plant. It is estimated that some 300,000 underground fuel storage tanks may

be leaking in the United States alone. In 1994, the military departments and Department of Defence (DoD) agencies estimated they had more than 20,000 underground storage tanks (USTs) that did not comply with EPA regulations.

2.2.5 Pollution Prevention

36 Recent studies conducted in Europe, the United States and Japan noted alarming correlations between combustion product emissions and the increase of cardio-vascular as well as respiratory and pulmonary disease. Carcinogenic effects have also been identified in animals when exposed to high concentrations of HCs. The sub-micron size and the chemical composition of particles found in automotive exhausts are the main offenders. These minute particles remain air-borne and are prone to infiltrate the pulmonary system. Some studies are going on in order to improve our understanding of the underlying mechanisms and to measure the impact of these emissions on human health. Nevertheless, a common agreement is emerging that it is necessary to reduce HC exhaust emissions.

37. Prevention of hydrocarbon pollution depends both on both human and technological factors. NATO can bring base and ship operations into compliance with existing legislation through educational programs, equipment modification and changes in product specifications. Increased emphasis must be placed on risk assessment and its reduction or mitigation. Further R&D emphasis should be placed on finding alternative fuels, selecting improved technology engines and power plants, finding better ways to scrub exhaust emissions, encouraging proper waste treatment and improving the quality of storage facilities. Early problem identification and intervention will be more cost effective than the end-of-the-pipe cleanup activities that are now being dealt with by alliance members.

2.2.6 The Military Logistics Chain

38. Prevention of hydrocarbon pollution inevitably requires the successful fusion of human effort and technology. For the purposes of this study, we have created a model illustrating the military petroleum logistics chain (Figure 2.1). The military has control, within national regulations, of the storage and handling of petroleum products. However, the military has limited control over fuel, lubricants and engine design. These sectors will continue to be driven by available commercial technology and environmental regulations.

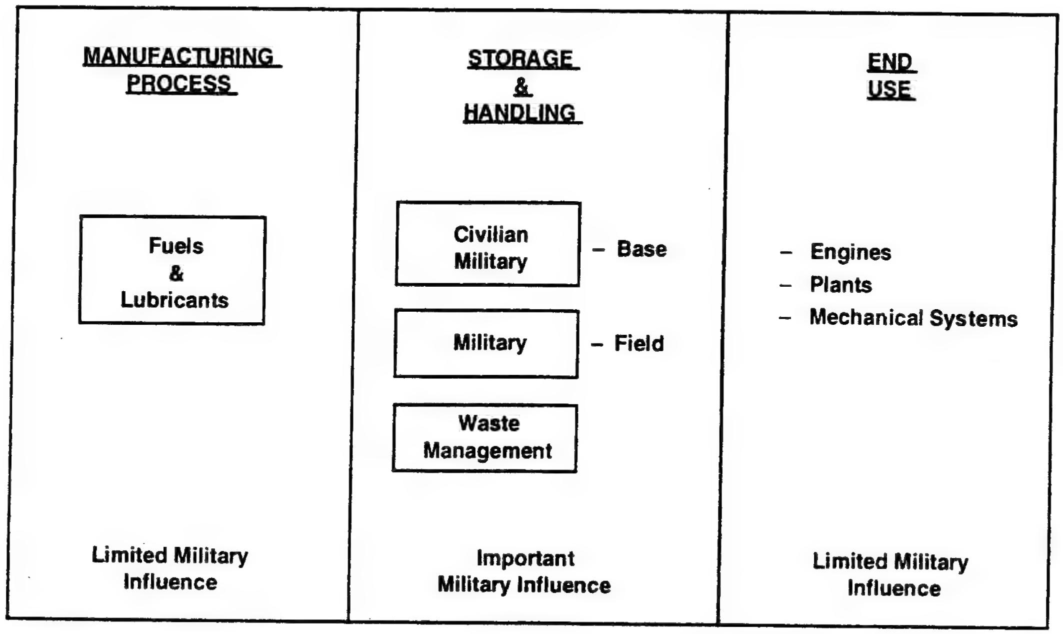

Figure 2.1. Petroleum, Oil and Lubricants: The Military Factor

2.3 SOLUTIONS

2.3.1 Petroleum, Oil and Lubricants Improvements

39. POL improvements are already occurring in response to environmental legislation. Environmental limits are designed to minimize emissions and to allow more effective treatment by external devices. For example, NATO STANAG 3747 has been amended to reflect the requirement for a reduced sulfur content and the specification for Diesel F54 is being amended to reduce the allowable sulfur level from 0.3 percent to 0.05 percent. These changes require modifications within the refining processes that are expensive and add time to the process. Changes in POL specifications may also require concurrent changes at the point of use in the form of engine or fuel system modifications.

2.3.1.1. Gasoline Improvements

40. Due to widespread use of unleaded gasolines and the general move to incorporate catalytic converters in vehicles, oil refiners are obliged to improve their technologies in order to produce higher octane number gasolines. For this reason, several new processes have been developed (e.g., parafines isomerization, alkylation, oligomerization or etherification of olefines). Additives such as methyl tributyl ether

(MTBE), tertioamyl methyl ether (TAME) or ethyl tributyl ether (ETBE) are now highly favored to enhance octane number and lower emissions.[3]

2.3.1.2 Gas-Oil Improvements

41. The petroleum industry is working together with engine manufacturers to produce cleaner and more efficient POL. Studies are also being conducted to find alternative gas-oils, potentially based on the conversion of natural gas or vegetable oils, which may be less polluting.

2.3.1.3 Lubricant Improvements

42. New biodegradable lubricants exist in the marketplace and have some limited applications for military employment. In addition, lubricants are being continually modified to meet changing end-user and environmental requirements.

2.3.1.4 Alternative Fuels

43. Studies continue using test fleets of special vehicles—usually buses, but also vans and automobiles—powered by alternative fuels. It should be noted that alternative fuel sources may create pollution streams of their own, e.g., batteries. Some vehicles have been converted to run on gasohol produced from sugar cane or sugar beet alcohol. These fuels are composed of an ethyl alcohol, methanol and isopropanol mixture. Today, 80 percent of the cars in Brazil have been converted to sugar cane alcohol.[4] Diesel engines powered by biocarburants are currently in operation. Studies have demonstrated that fuels suited to long-term use and which evidence low levels of pollution are available: they are termed biodiesels and are vegetable oil-based. In a recent test, a diesel engine was supplied with a biodiesel made from 70 percent soybean oil and 30 percent diesel blend without requiring engine modification. Experiments were also conducted over a 2-year period using two Mercruiser (180 h.p.) diesel outboard motors operating for 3600 hours. The list of parts replacements was short: three starters, two alternators and one joint. Major advantages of this biodiesel (now sold in 200 specialized gas stations throughout the United States) are a significant reduction in gas emissions and a 30 percent reduction in fuel consumption. Furthermore, biodiesel is not volatile when compared to hydrocarbons. The logistics implications are evident: reduced pollution and greatly reduced shipping volumes and weights to perform a mission. France has produced diestair, a biofuel containing 30

---

3 More information on this is available from Mr. Bernard Tramier at Elf Aquitaine Paris (see reference annex). Also see Pascale Scheromm, "Biocarburants: A vos marques," Biofutur, October 1991, pp. 18-24.

4 More information on this is available from Mr. Bernard Tramier at Elf Aquitaine Paris (see reference annex).

percent vegetable oil; availability is limited, however. It must also be noted that biodiesels are not suitable for use in freezing temperatures due to wax formation.

44. Diesel engines reach very high combustion temperatures regardless of the fuel type used. Diesels may therefore be as polluting as those using conventional fuels with regard to nitrogen oxides, carbon monoxide and carbon dioxide.[5] Vehicles converted to electric battery power have also been designed. Even though electric vehicles eliminate tailpipe emissions, there are several disadvantages including range, power and torque limitations. The need for external power supplies and the time required to recharge batteries may preclude military use during deployments. Furthermore, batteries must be recycled at the end of their useful lives.[6]

45. Other alternative fuel sources are being studied. All are aimed at reducing vehicle exhaust emissions. Some of those being evaluated currently are: compressed or liquefied natural gas, liquid propane, solar energy and biodiesel.[7] From a military perspective, while alternative fuels may show promise in a non-operational environment, their use in an operational theater would contradict the NATO Single Fuel Concept and may be limited by ambient temperature considerations. Also, while these improvements are of interest to NATO, progress depends on oil industry efforts; NATO cannot dictate changes to POL specifications without the support of the oil industry.

2.3.2 Storage and Handling

46. Storage and distribution as depicted in the LTSS/44 model (Figure 1) is the period between acceptance of fuels and lubricants up to the time of their delivery to the end-user. Most military POLs are handled at fixed bases where the storage and handling problems mirror those of civilian counterparts. However, the pollution risks associated with military field operations are significant, despite the fact that only a small percentage of military POL is used in these theaters. Storage and handling are regulated by NATO standards such as STANAG 3609 and 3784. Most countries have independently enacted legislation specifically directed at POLs and have conducted surveys of their strategic

---

5 Ibid.

6 Ibid. Others to be contacted are Mr. Claude Gatelier and Mr. Jean-Paul Vandecasteele at the Institut Français du Pétrole (IFP), Biotechnology Department (see reference annex).

7 See Robert Kauffman et al., "Lubricant Segregation for Recycling and Reuse," Third Annual Air Force Worldwide Pollution Prevention Conference, 29 August-1 September 1994, San Antonio, Texas; Paul R. Therrien, "Alternative Fuels," at the same conference, and "Monitoring the Tinker Air Force Base Alternative Fuel Fleet," Technical Progress Report No. 3, ITT Research Institute, BDM Federal, 15 June 1993.

underground storage facilities. A 1993 study addressed standardization of environmental protection regulations for hydrocarbons.[8]

2.3.2.1 Prevention and Control Strategies

47. Some NATO nations have developed a strategy for the prevention and control of petroleum pollution incidents. Although the risks of an uncontrolled spills are greater in the field, prevention and control strategies for base and field are identical. In the United Kingdom (UK), for instance, a handbook has been written giving instructions to be applied in case of real or eventual pollution risk. It is frequently revised with regard to technological progress and acquired experiences. Several main guidelines are followed in case of potential or real incidents.[9] In all cases it should be expected that NATO forces will have to comply with the most restrictive legislation present in country.

48. The first objective is to prevent hydrocarbon pollution. The following approaches are suggested:

A. Establish and maintain POL management structures in accordance with national, European and NATO norms;

B. Establish NATO education and training programs that stress proper handling and management of POL stores;

C. Disseminate information quickly and accurately throughout NATO, which describes the causes and consequences of POL pollution.[10]

49. The second objective is to control hydrocarbon pollution:

A. By proving the validity of the equipment used for pollution control;

B. By ascertaining that concerned people have been properly trained to control pollution; and

C. By assigning specific responsibilities to each person in order to allow a clear and precise coordination of action.[11]

---

8 See Annex I, NATO PHE Working Party Environmental Questionnaire, 25 February 1993.

9 UK MOD Petroleum Pollution Reporting System.

10 Squadron Leader David Honeyman, RAF Policy for the Prevention and Control of Oil Prevention.

11 Ibid.

2.3.2.2 Pollution Detection

50. Hydrocarbons in groundwater must be evaluated by reliable means of detection. A network has been developed to be implemented in case of a (recent or ancient) leak or accidental dumping of oil product in the soil. Actions taken first focus on an evaluation of the underground water contamination risk and eventually define protection and rehabilitation methods.[12]

51. Several solutions are possible:

A. Core-sample collection and monitoring (quality and bacteriological test);

B. ROCK-EVAL (rock-evaluation) measuring and recording qualitatively and quantitatively a soil state; and

C. Analysis of pollution by reverse chromatography coupled to a portable mass spectrograph.

52. The best way to prevent pollution is to use contamination sensors. Several types of sensors suitable for development into POL screening devices have been identified:

A. Vapor contaminant sensors;

B. Liquid conductivity sensors;

C. Viscosity sensors; and

D. Variable wavelength infrared sensors.

These are each described in Appendix A.[13]

2.3.2.3 Storage Improvements

53. Most countries in the alliance have enacted regulations or plans to replace leaking underground storage tanks, or to improve tanks that are not complying with

---

12 For more information, contact Mr. Claude Gatelier and Mr. Jean-Paul Vandecasteele at the Institut Français du Pétrole (IFP), Biotechnology Department, and Centre d'Etude et de Documentation de Retraitement de l'Eau (C.E.D.R.E) (see reference annex).

13 All future references to appendices in this and subsequent chapters are in the document entitled Technical Data and Information: Appendices to LTSS/44 Report.

environmental laws. In 1994, US military departments and DoD agencies estimated they had between 23,000 and 24,000 underground storage tanks that did not comply with revised regulations. The US Defence Logistics Agency (DLA) has an initiative under way to retrofit floating-roof, above ground petroleum storage tanks.[14] Pollution prevention activities include site inspections, tank evaluations, more reliable leak detection equipment and the development of coordinated approaches and strategies for quick cleanup following accidents.

54. Several technologies for improving storage are currently available; they are described in Appendix B.

2.3.2.4 Waste Management

55. Items that do not meet specification or for which shelf lives have been exceeded are clean wastes. From the standpoint of disposal, they are to be treated the same as new, on-spec items, in terms of pollution problems. The pollution from these items can be minimized by proper logistic management. The off-spec or out of date products are easier to handle for disposal than used lubricants, which are contaminated and must be handled differently, i.e., as a hazardous waste.

56. All disposal must be in accordance with local laws. The most common approach is to transfer waste to a licensed disposal/recycling contractor. Environmentally, the preferred approach is to re-refine lubricating oils for reuse or combustion as heating oil. Details of new waste oil treatment techniques are provided in Appendix C.

2.3.3 End-Use System Improvements

57. For the purposes of this study, end-use systems are defined as those that use POL products. End-use systems pollute by using products that produce emissions, are disposed of in normal maintenance operations, and may boil off or be a washdown during operations. Significant efforts are being made to reduce pollution by improving engine technology (see Appendix D for more detail). Pollution prevention is accomplished by minimizing fuel consumption, optimizing fuel combustion, and by treating exhaust gases. However, the long life-span of end-use systems limits the rate of improvement in this area.

---

14 This US information was provided by J. Kennedy, Office of the Under Secretary of Defence for Environmental Security, Pollution Prevention.

2.3.4 Type of Technology

58. To conclude this discussion about possible solutions to the POL problem, the following technological and management improvements would help minimize future POL pollution:

A. Use alternative POLs and new energy sources;

B. Improve infrastructure, implement a pollution prevention strategy, improve storage and handling techniques;

C. Recycle wastes;

D. Improve engine design to reduce consumption and emissions; and

E. Design end-use equipment to minimize pollution.

2.4 STATUS OF EXISTING TECHNOLOGY

59. Certain POL improvements have already been applied, such as unleaded gasoline, low sulfur diesel, redesigned engines and emission control systems. Most of the other solutions described above may be implemented within the near future (less than 5 years). Obviously all areas require improvement, but better management of the military logistics chain, coupled with a pro-active pollution prevention strategy, offers the most cost-effective improvement in the short-term. In addition, some alternative fuels may be available in 5 to 10 years. However, even if broadscale use of alternative fuels is achieved in isolated cases (Brazil), such solutions will probably not be implemented in the near or intermediate term (up to 10 years) and are unlikely to be suitable for field use 5959.

60. Storage safety improvements are already being enforced on oil tankers by requiring double walled tanks and double hulls. It is important to consider other possibilities that can be currently implemented; as an example, an oil resistant concrete has recently been patented and should be encouraged for commercialization by specifying the new concrete in NATO military specification (STANAGS).

61. Used oil recycling has existed for several years, but this process needs to be improved to achieve economic gains. Existing prices for recycled products exceed those for new oil. An experimental study has shown that a pyrolysis process is currently available for destruction of used oils.

62. Engine improvements are continuously being made to reduce and clean up waste gas emission streams; catalytic converters and multiport injection are two examples.

This work is being led by industry in response to changing legislation. Broad use of a completely redesigned two-cycle engine is not believed feasible within the next 5 or 10 years. The same is true concerning cleaner marine engine development. International regulations agreed to at the Bodensee meetings in 1993 will be implemented in the near future and will exert substantial pressure on clean engine development.

2.4.1 Anticipated Problems

63. The following areas have been identified by the LTSS/44 Study Group on POLs as likely future issues affecting pollution prevention efforts in this area:

A. Gasolines. Studies on the long term toxicological effects of gasolines, and especially their additives, have yet to be conducted. It is interesting to note that gas-oil was originally presented as less polluting than gasoline alone. Now the general trend is to expect just the opposite result as part of the continuing product evolution and testing cycle.

B. Alternative fuels. The lack of infrastructure could slow the introduction of alternative fuels in non-operational roles. However, such fuels do not have an application in the battlefield environment.

C. Storage. Changes in storage regulations and environmental legislation are expensive and time-consuming to implement.

D. Used Oils Recycling. The technology has been available for several years, but it is still not applied systematically. Recycling processes and problems in used oils recovery often make the recycled product more expensive than a new one. This naturally reduces the user's interest in exploiting this technology, despite the apparent environmental benefit.

E. Engine Problems. Military vehicles are normally maintained in the inventory for longer time periods than the average civilian vehicle. For this reason, advances in engine and vehicle technologies that reduce pollution will be introduced more slowly into NATO military fleets.

F. Catalysts. The use of catalysts continues to be limited by available technology and costs. Catalytic converters presently have a lifetime of about 80,000 km, but is believed that research should be able to extend converter lives significantly.

G. Costs. Changes in environmental legislation, which are needed to spur environmental R&D, impose costs upon governments, industry and the military.

2.5 CONCLUSIONS

64. The LTSS/44 Study Group on Petroleum, Oil and Lubricants (POL) defined three stages in the life of POLs, all of which affect the environment: production by manufacturers, storage and handling and end-use. Militaries are only minor users of POL in the global context. Therefore, they have limited influence on POL production and end-use system design. The focus of the militaries' efforts should thus be on the storage and handling process. A failure to handle petroleum products properly can limit or stop military training and peace time operations.

65. With a few minor exceptions, appropriate technologies are available to improve POL storage and handling. Therefore, further scientific study is not required; rather, the military should concentrate on implementing existing technologies. What is still needed is a Petroleum Pollution Strategy Plan, based on a clear assessment of the risks at fixed or fielded locations and on the training of personnel, including infrastructure control procedures.

66. Most advances in POL production and end-use technology will come from the civilian market. The military will need to adapt these technologies to meet their specific requirements.

67. Other, more specific conclusions reached by the group are as follows:

A. While the means to achieve significant degrees of pollution prevention for POLs are already available, more studies are required to improve existing techniques and to better identify the different processes and the ways in which they would be employed.

B. From a military perspective, alternative fuels may have some use in a non-operational environment, but their use in an operational theater would contradict the NATO Single Fuel Concept and may also be limited by ambient temperature considerations.

C. The mandatory switch to unleaded gasoline and the wide adoption of catalytic exhaust system equipped vehicles are now demanding that refineries improve their production technologies used to produce higher research octane number (RON) gasoline. New processes have been developed, e.g., paraffin's isomerisation, alkylation, oligomerisation or

etherification of olefins. Additives such as MTBE, TAME or ETBE are now highly favored to enhance the octane number while reducing harmful emissions.

D. POL improvements are of vital interest to NATO, but progress must rely on improvements made by the oil industry. As one, non-dominant customer, NATO may not be able to dictate changes to POL specifications for normal use.

E. The petroleum industry and engine manufacturers are working together to produce cleaner and more efficient POLs. Studies are also being conducted to find alternative gas-oils, potentially based on conversion of natural gas or vegetable oils, to further reduce pollution from internal combustion engines.

F. New biodegradable lubricants exist in the marketplace and have found some limited applications in the military environment. In addition, lubricants are being continually modified to meet changing end-user and environmental requirements.

2.6 RECOMMENDATIONS

68. The following are recommended as action steps for the NATO military forces:

A. Reduce or, if possible, eliminate polluting sources by modifying fuel oil and/or making engine improvements. Research more thoroughly the uses of catalysts, the catalytic additive known as EOLYS, self-cleaning catalysis, and clean ship engines.

B. Substitute alternative fuels when possible and continue to identify new, lower polluting energy sources.

C. Vaporize wastes using pyrolysis, and continue to improve and reduce the cost of used oil recycling.

D. Work to improve the POL infrastructure through support for specific regulations, controls and improved storage requirements.

E. Promulgate and embrace environmental security regulations, develop better means of control, conduct ongoing research in the treatment of

contamination from POLs, provide professional training and continue to develop information to gain a better understanding of environmental risks.

F. Conduct further study on: waste management techniques, leak detection systems (especially for underground storage tanks) and the redesign of end-use equipment (especially for field use) to minimize spills and leaks.

G. Work to decrease the numbers of POLs on NATO's approved list.

(This page intentionally left blank)

CHAPTER 3

MUNITIONS, ENERGETICS AND PROPELLANTS

3.1 INTRODUCTION

69. The production, use and disposal of conventional munitions is harmful to the environment. Most munitions are designed to kill and destroy, and are a source of pollutants throughout their entire life cycle, from the concept phase to their final disposition. To date, there has been considerable effort to abate pollution caused by the production and use of munitions. However, in the future, pollution prevention must become an important aspect in the development of new munitions.

70. This study of pollution prevention in munitions covers:

A. Environmentally acceptable munitions for the future; and

B. Environmentally acceptable disposal of obsolete or unserviceable munitions.

71. This review does not cover:

A. Operational use;

B. Clearance of unexploded ordnance from ranges and Explosive Ordnance Disposal (EOD) procedures; or

C. Abatement of environmental burdens on training areas caused by munitions (site remediation).

72. When discussing munitions, one important rule must never be forgotten: Safety is the most important requirement for munitions. Safety overrides performance requirements and concerns for the environment.

3.2 IMPLICATIONS FOR THE MILITARY MISSION

73. In light of increasingly restrictive environmental laws and regulations, it is often a problem to use existing technologies and systems for the development, production, use and demilitarization of munitions. Moreover, certain suitable technologies are accepted by some nations but are not accepted by others; this lack of a uniform approach can pose difficulties for NATO forces training in each other's countries, for example.

74. There could also be limitations on the military's use of pertinent facilities (proving grounds, training areas, etc.) due to the cumulative effects of past contamination (especially heavy metals).

3.3 TECHNOLOGIES AND APPROACHES

75. From an environmental perspective, any development program for new munitions should strive for an environmentally acceptable solution to fulfill the performance objectives, bearing in mind that each munition has a specific task.

76. Of paramount importance is the elimination of toxic substances in the production processes and the reduction of other environmentally harmful components throughout the service life of the munitions. It is also necessary to consider the environmental impact of proposed substitutes. Available resources should be concentrated in areas that will be most beneficial to the military mission and the environment.

77. Military requirements for the development of new weapon systems must also take into account environmental issues. Consideration of the environment at an early stage affords the best opportunity to minimize the environmental impact in a cost-efficient way. Environmental compatibility must be viewed for a weapon system as a whole, including: munitions, maintenance, training (using simulators whenever suitable) and demilitarization. Of course, environmental considerations are not the sole deciding factor: a munition that is environmentally acceptable, but which proves ineffective will be rejected by the military user.

78. Pollution prevention problems for munitions can be divided into four life cycle areas: development, production, use and demilitarization. Figure 3.1 shows the phases and subphases of the munition life cycle.

79. Neglecting or omitting environmental considerations during an early stage of the munitions life cycle will increase environmental problems and costs in the subsequent phases. For the various phases and subphases, different ways of implementing pollution prevention are feasible. Each of these is addressed in the following sections.

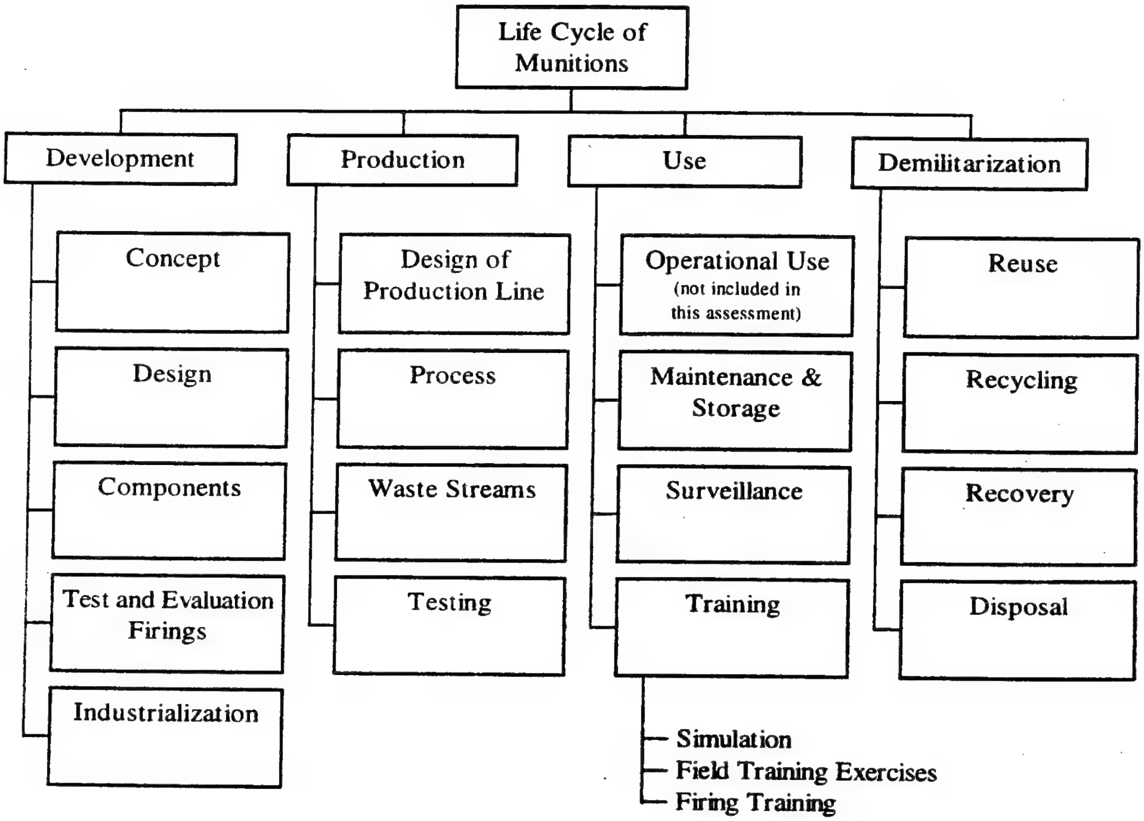

Figure 3.1. Life Cycle of Munitions

3.3.1 Development

80. The environmental impact of a system is determined at an early stage of its life cycle. The key to success is consideration of environmental issues during the system's development phase.

3.3.1.1 Concept

81. Environmental compatibility must be addressed early in the concept phase. This issue must be a viable part of all trade-off studies, since the further development proceeds, the more costly it will be to implement changes. The program manager has many responsibilities, one of which is compliance with all applicable environmental and safety laws (federal, local, etc.); an example in the United States is compliance with the US National Environmental Policy Act (NEPA). The development

contractor/agency is required to develop and implement an environmental impact plan early in the concept development. This plan spans the whole life cycle and must include:

A. Identification of all environmental concerns;

B. Identification of all hazardous materials;

C. Hazard evaluation; and

D. Trade-off analysis.

82. This should be a continuous program, constantly updated throughout the various project phases. The focus of this analysis is pollution prevention with a fallback position of pollution abatement. When pollution abatement is the only alternative, the analysis must address the availability of the required technology. This analysis also identifies required technology investments early enough to ensure availability in a timely manner. Therefore, the most important factor is to implement environmental assessments during the concept phase.

3.3.1.2 Design

83. During the design phase, trade-off studies address the consequences of various hazards both from the perspectives of munitions safety (safe spacing and probability of an incident) and environmental safety (fate and effects considerations). Zero tolerance is not a viable alternative for munitions; therefore, acceptability must be the focus. Hazard evaluation must be an integral part of the system engineering process similar to those of predictability and reliability. Although environmental issues should not override system performance requirements, these issues may be the discriminator between otherwise equal alternatives. Therefore, making an informed decision in early design would eliminate the need for providing pollution abatement in production or in-service operations. The US Army Materiel Command has published a "Materiel Developers Guide for Pollution Prevention," which describes the management of environmental work during the development phase.

3.3.1.3 Components

84. A wide range of materials are used in weapon systems. These vary from explosives, to metals and plastics, to electronic circuit boards. This section considers only those materials that are either unique, or specific, to munitions.

85. Munition components are selected based on their function in assuring performance objectives, but consideration also should be given to their impact on the

environment and human health. The following paragraphs discuss some of the environmental problems and efforts to alleviate or eliminate toxic components used in munitions.

86. Material used in munitions should be as environmentally acceptable as possible. The choice of material depends on its function and overall contribution to munitions performance. Material from a munition can stay in the field, be collected after use or be a concern in a disposal process.

87. Research is ongoing to find solutions in this field. For example, in Germany, a study is being conducted to replace plastic materials used in munitions with biodegradable thermoplastics based on renewable resources.

3.3.1.3.1 Heavy Metals

88. Heavy metals, such as lead, mercury, antimony and depleted uranium, are widely used to enhance munition performance. At the same time, they are a source of environmental concern. Lead and antimony are used as material for bullets in small caliber ammunition. Lead foil is used as a decoppering agent in barrels of artillery cannons. In rocket propellants, lead compounds are used to moderate the burning characteristics of propellant. Lead styphnate, barium nitrate and antimony sulfide are used in primer compositions. Lead azide is one of the most widely used primary explosives in detonators. Depleted uranium is used in projectiles to enhance penetration. Soils, sediments, surface and groundwater contaminated with heavy metals are difficult to treat and result in costly remediation efforts.

89. As a result, several NATO countries have made efforts to reduce or eliminate heavy metals from munitions. In the United Kingdom, one way to reduce lead is to change the material of bullets and shot from lead to steel. In Germany, a lead-free initiator for small caliber ammunition has been developed, and is currently in use for 7.62-mm ammunition (it is also planned for use in the United States, under the Green Bullet Program). In the United States, research for a lead-free rocket propellant is ongoing. Another option to reduce the use of lead in primers being examined in the United States is the use of a laser to ignite propellants in larger caliber weapons. This represents a change of the whole ignition process. Also, the United States has found a suitable non-lead foil and has identified several promising non-polluting candidates at the basic research stage to replace lead azide.

3.3.1.3.2 Smoke/Pyrotechnics

90. Smoke munitions are widely used. Recently, UN peacekeeping operations have further heightened interest in smoke munitions. One of the greatest problems in using

smoke for camouflage is the toxic ingredients; for example, barium compounds are used in pyrotechnic compositions. In various countries the use of smoke munitions for training or test and evaluation purposes has been restricted. In Germany, a smoke grenade has been in service since 1995 with a smoke agent (visual camouflage) that has no evidence of toxic effects on people. Also, a smoke agent with visual and infrared screening capability has been developed and will be introduced into service in 1996. The United States is also investigating the replacement of barium in green smoke compositions.

3.3.1.3.3 Ammonium Perchlorate

91. Composite propellants, containing ammonium perchlorate, for rocket motors produce hydrogen chloride when they are burned. This hydrogen chloride reacts with water vapor in the air producing hydrochloric acid, which then pollutes the atmosphere. The United States is investigating use of ammonium dinitramide as a replacement for ammonium perchlorate to eliminate this problem.

3.3.1.3.4 Nitrocellulose-Based Propellants

92. Multi-base propellants contain nitrocellulose and nitroglycerin in their formulations. These propellants are currently not recyclable and consequently surplus nitrocellulose-based propellants must be open burned or incinerated, thus contributing to hazardous air emissions. The United States is pursuing development of thermal plastic elastomer propellants, which offer promise as recyclable material.

3.3.1.4 Test and Evaluation Firings

93. Although pollution during military operations is not considered in the framework of this study, a major concern that is addressed is the pollution caused by testing (both developmental and operational). Therefore, the environmental impact of testing munitions should be minimized by the increased use of simulations and surrogates, where practical. This proactive approach will reduce the volume of new pollutants at test ranges. In addition, test procedures employed by the test community should be continuously reviewed in order to minimize their environmental impact, for example by combining tests. More importantly, the results of these reviews should be provided to the users and developers such that this data can influence future design efforts.

3.3.1.5 Industrialization

94. Affordability is becoming the prime factor for new weapon systems development. Therefore, in many cases performance attributes, once thought to be sacred, are now tradable for a more producable (cost effective) system. Thus, it is important to provide the developer the overall environmental goals and allow latitude to achieve the

"best value" product. This may mean achieving an "eighty percent solution" in many areas, including environmental aspects. All processes for producing the system will be determined in the development phase and refined during the production phase. Therefore, the environmental impact of these processes must be addressed during development. Any subsequent process changes may obviate all previous testing and thus jeopardize the entire project.

3.3.2 Production

95. During production, defence industries encounter the same environmental problems as other industrial branches. Thus, programs and procedures for pollution prevention or abatement are similar, and information and possible solutions can be shared.

3.3.2.1 Design of Production Line

96. The design of the production line must take into account the environmental impact of the production process. All toxic and hazardous materials must be handled properly and all wastes must be treated to meet environmental laws and regulations. Recycling, reuse and recovery of ingredients should be considered wherever possible and where recycling will not adversely affect the required performance. As mentioned previously, pollution prevention must be considered in the development phase because requalification in the production phase may not be cost-effective.

3.3.2.2 Process

97. The process designed with the environment in mind should reduce wastes and by-products. For example, process solvents should be selected that are environmentally benign, wherever possible, and the quantities and types of waste sent to the treatment plants must be considered. During the production of propellants, large quantities of solvents are used. These solvents are a volatile organic compound (VOC) problem during processing and also are a residual in the propellant for a while. Depending on the type of propellant, environmentally harmful vapors are emitted not only when the propellant is fired, but also when it is in storage. In the United States, a study is under way with the objective of eliminating solvents in the process. The handling of heavy metals requires special precautions for workers during manufacturing (for example, grinding of lead components and materials used to produce depleted uranium). The US Navy is pursuing solventless processes for pyrotechnics in order to reduce VOC problems in production.

3.3.2.3 Waste Streams

98. All waste streams from the production of propellants or explosives are collected, recycled or treated. The goal is "clean manufacturing." Environmental permits

are becoming more and more restrictive in all countries. The quantities of wastes generated must be reduced and wastes that were recently acceptable may not be acceptable in the near future. Regulations may prevent construction of a facility to produce a new munition no matter how important this new munition may be to a nation's military mission. There are also waste streams where the only technology currently available is incineration. One example is the waste generated from trinitrotoluene (TNT) purified with sodium sulfite.

3.3.2.4 Testing

99. During production, there is "in-process" testing and "lot acceptance" testing. In-process testing is most important from an environmental perspective because it reduces scrap. The earlier anomalies are identified in the production process, the greater the chance of correcting the problem. Lot acceptance tests are the final test before acceptance into the inventory.

100. Firing ranges are contaminated with lead, depleted uranium, unexploded ordnance, energetic residues, etc. Metal oxides emitted during testing contribute to hazardous air pollutants. Environmental assessments must take this into account in future munition development. Although simulation exercises do not generate pollution, there will always be a requirement for live munitions firing to evaluate safety and suitability for service.

3.3.3 Use

101. If not stored properly, munitions may cause major environmental problems during their in-service phase. Three categories of use are considered here: maintenance and storage; surveillance; and training. As mentioned above, operational use of munitions was not considered in this study.

3.3.3.1 Maintenance and Storage

102. Munitions spend the majority, if not all, of their service life in storage. While storage has very little impact upon the environment, the safety of munitions while in storage is essential to prevent a major disaster. To this end, munitions are subject to rigorous maintenance inspections and surveillance procedures. Here it is important to consider each process to ensure that munition safety and environmental requirements are met. At no time should safety be jeopardized.

3.3.3.2 Surveillance

103. Surveillance programs are in place to ensure that munitions are safe and suitable for service. Most armed forces have a periodic inspection program in effect to

assess the extent of deterioration in munitions over time. Some munitions also require periodic testing or proving in order to assess their reliability over time. Here, predictive technologies that are currently being developed may help to reduce and even eliminate the requirements for periodic testing of munitions throughout their service life.

3.3.3.3 Training

104. During peacetime operations, the impact of munitions on the environment is subject to considerable scrutiny from the public and environmental groups. Therefore, it is paramount that the armed forces properly address the use of munitions during training to achieve an adequate balance between operational readiness and environmental impact. As noted earlier, the environmental impact should actually already have been considered during the development of a weapon system. Otherwise, addressing the environmental consequences becomes extremely costly and difficult to rectify during the in-service phase.

3.3.3.3.1 Simulation Training

105. Simulation training provides military personnel training in the use and/or function of a weapon system without actually using any live munition. Simulation training has several distinct advantages. It is beneficial because it reduces training costs and minimizes the environmental impact resulting from munition use. It is also an important tool for training personnel in command and control procedures.

3.3.3.3.2 Field Training Exercises

106. Notwithstanding the efficiency of simulation training, there comes a point where armed forces must put all their training into practice. This is when training munitions are predominantly used to simulate a battlefield situation. Here, it is desirable that the munitions being used provide operational realism while having little or no impact upon the environment.

3.3.3.3.3 Live Firing

107. Live firing should be the culmination of training. It is required to provide military personnel with realistic training and the stress associated with live munitions use. The quantity and type of munitions used during a live firing should be commensurate with the need for realistic training.

3.3.4 Demilitarization

108. The development of new technologies for the "Design for Demilitarization" will eventually have an impact on the demilitarization of munitions; however, it is estimated that this work will not have an impact on operational demilitarization techniques for at least the next 10 to 15 years. New munitions must therefore be designed for disposal utilizing the demilitarization technologies that are likely to be practical and available at the end of the planned service life of the munition. For existing munitions in several nations, work is under way to improve existing disposal techniques. For example, the United States has already built a large pilot plant in Utah that has demonstrated recovering nitramines using ammonia extraction from rocket propellant. There are other techniques available for recovering nitrocellulose from propellant and reusing it in ball powder. TNT steam and melt-out processes also exist.

3.3.4.1 Definitions

109. The following definitions have been used for the purpose of this study. These definitions have been derived from, but are not necessarily the same as, those used in the Draft STANAG 4518 (Edition 1). It is recommended that the following definitions be adopted by NATO:

110. Demilitarization: The neutralization of the offensive or defensive potential of ammunition and explosives, in a safe, non-toxic, practicable and environmentally benign manner, in order to ensure that they may no longer be used for either their original purpose, or for any illegal explosive purpose.

111. Reuse: The application of component parts of the munition or its packaging to other explosive systems.

112. Recycling: The reuse of the constituent parts of a munition in order that these parts may be utilized for other economic purposes, that may or may not include further explosive uses.

113. Recovery: The reclamation of elements, compounds or parts from a munition in order that they may be used for other economic purposes, that may or may not include further explosive uses.

114. Disposal: The work performed on ammunition and explosives that are no longer required in order to destroy or otherwise redistribute the residual materials in a safe, non-toxic, cost effective, practicable and environmentally benign manner.

3.3.4.2 Explosive Safety Legislation

115. Demilitarization operations are always conducted in accordance with the relevant national explosive safety legislation. These regulations must always take precedence over any environmental legislation, as safety must be the overriding priority during demilitarization operations. Risk assessments of demilitarization technology and techniques must be conducted to ensure that together they guarantee a safe system of work.

3.3.4.3 Environmental Legal Requirements

116. Existing legislation in NATO nations requires that, as far as is reasonably practicable, employers have due regard for the health and safety of not only their own employees, but also self-employed persons and contractors who are working at the site and members of the public who may be affected by the employers' activities. A fundamental requirement of this legislation is that exposure to hazardous substances must be prevented. Where this is not reasonably practicable, exposure must be adequately controlled.

117. Environmental legislation generally covers three areas:

A. Industrial processes;

B. Waste disposal; and

C. Smoke, fumes, gases or noise emitted from premises so as to be prejudicial to health or to act as a nuisance.

It is likely that environmental legislation at all levels will continue to impose, or recommend, more stringent standards. Therefore, in order to anticipate these developments, and then comply with them, demilitarization technology must continue to develop on an evolutionary basis. Radically new demilitarization technology should be developed, with the emphasis predominantly on resource recovery rather than destruction.

3.3.4.4 Stockpile Reduction Options

118. There are three generic options available within NATO countries to reduce stockpiles of ammunition and explosives. These are generally accepted to be, in priority order:

3.3.4.4.1 Use for Additional Training

119. The idea of reducing munitions stockpiles by using them for additional training exercises has only restricted applicability. This option is limited by the environmental and financial constraints on army, naval and air force training.

3.3.4.4.2 Sale/Gift

120. The sale or gift of surplus ammunition and explosives is a politically sensitive issue, which involves factors that are beyond the scope of this paper. The sale of surplus munitions effectively delays the demilitarization operation until a later date. On the one hand, this delay may mean that new technology would be available to demilitarize the munitions in a more environmentally benign manner. On the other hand, there is also the danger that the end user may not adopt the Best Environmental Practical Option (BEPO) approach for the munitions' eventual demilitarization.

3.3.4.4.3 Disposal

121. Work is performed on ammunition and explosives that are no longer needed in order to destroy or otherwise redistribute the residual materials in a safe, non-toxic, cost effective, practicable and environmentally benign manner.

3.3.4.5 Demilitarization Technologies

122. There are a wide variety of demilitarization technology options available to the demilitarization community. Some have been proven on a production basis, while others are still under development and have only been demonstrated on a laboratory scale. The main incentives for the development of this technology include the size and diversity of national stockpiles, the geographic dispersion of the stockpiles and the simple need to provide the user with a modern, environmentally benign capability.

123. Many other challenges that are related to environmental and strategic issues have also established the need for a coordinated development effort focused on resource recovery and disposition. This is a practicable option for those nations with large, generic types of stockpiles; however, it is not economically sound for nations with small stockpiles of many different types of munitions.

124. Historically, standard techniques of removal, disassembly, incineration or open burning/open detonation were viewed as being both safe and logistically efficient. As environmental awareness increased, the requirement for alternative destruction technologies and enhanced recovery processes began to emerge. However, there has been no coordinated international research and development effort, or collaboration, due to the

particular demilitarization problems and differing environmental legislations of the individual member nations. In 1995, the NATO Maintenance and Supply Agency (NAMSA) published a study on legislation pertaining to demilitarization management and on the kinds of technologies now available for disposing of munitions. An analysis of current and future demilitarization technologies is contained in Appendix F of the document entitled Technical Data and Information: Appendices to LTSS/44 Report.

3.3.4.6 Findings

125. The development of alternative technologies will significantly reduce the requirement for traditional demilitarization techniques. There will, however, still be a requirement to dispose of ammunition by open burning or open detonation for reasons of safety or excessive cost. The fact that ammunition is "Designed to Kill" should always be kept in mind, when some of the more esoteric pre-processing techniques required before disposal are advocated.

126. The principle of Best Available Technology Not Entailing Excessive Cost (BATNEEC), (sometimes known alternatively as the Best Practical Economic Option, or BPEO), should be followed. The costs of storage, processing and transport must be taken into consideration when the financial cost benefit analysis is made.

3.4 CONCLUSIONS

127. The LTSS/44 Study Group on Munitions, Energetics and Propellants reached the following conclusions:

A. Environmental awareness has to be increased in the military arena with respect to munitions, propellants and energetics. Operational requirements both for training and peacetime operations should be revisited, taking into account environmental security considerations. As a result, military doctrine should be reexamined and modified, where feasible, to adequately reflect environmental concerns.

B. The environmental impact of existing munitions is not always recognized or specified.

C. The environmental impact of a weapon system is determined at the earliest stages of its life cycle. The key to success is consideration of environmental issues during the initial stages of development, i.e., concept and design. Early understanding of the environmental impact over the course of the life cycle of a weapon will enable industry to

provide more environmentally acceptable munitions. First steps in this direction have already been taken.

D. Efforts in research and development should concentrate on production and reuse. More R&D and operational changes are needed to provide both clean manufacturing and environmentally acceptable munitions and components.

E. Current disposal and reuse technologies for pyrotechnics are not environmentally acceptable. Therefore, further research is required. This is especially true since this type of munition is widely used in peacetime. Furthermore, the component life stability is estimated at 5 to 10 years.

F. The demilitarization phase needs to address and weigh environmental benefits versus cost considerations.

3.5 RECOMMENDATIONS

128. On the basis of this assessment of pollution prevention efforts pertaining to munitions, energetics and propellants, the following actions should be taken:

A. Conduct a symposium to raise environmental awareness among military personnel. The specific objective of the symposium would be to modify munitions requirements to adequately reflect environmental considerations.

B. Establish a Special Team of Experts to collect data about the environmental effects of munitions, especially during use in training. Create a database of this information in NATO.

C. Assemble a NATO-Guidance document entitled "Environmentally Acceptable Munitions" to catalog alternative munitions for specific purposes.

D. Establish a Special Team of Experts to identify R&D requirements for acceptable munition component substitutes necessary to meet mission requirements.

E. Initiate coordination of R&D on more environmentally acceptable and cost effective disposal technologies (including pyrotechnics) for larger munitions so that they can be safely destroyed and thereby reduce the current dependence on open burning/open detonation (OB/OD).

CHAPTER 4

FIRE SUPPRESSANTS AND REFRIGERANTS

4.1 SCOPE AND NATURE OF THE PROBLEM

129. The family of chlorofluorocarbons, or CFCs, was developed in the 1930s and has found many industrial uses over the ensuing decades. A wide of range of physical characteristics, including changes in the boiling point and partial vapor pressures, can be achieved by relatively slight changes in CFC molecular structures. This, coupled with their relative stability, low toxicity, ease of manufacture and versatility, made CFCs ideal candidates for a wide range of commercial and military uses. As industry expanded, so did new uses for these compounds. Eventual military applications for these chemicals included cleaning solvents, refrigerants and firefighting agents.

130. In the 1970s, atmospheric scientists began to investigate the ultimate environmental fate of these compounds, which were being emitted in large quantities to the atmosphere, and discovered that they react with ozone in the stratosphere to deplete the earth's ozone layer. The Nobel Prize was recently awarded to the three scientists who discovered that chlorine released into the stratosphere by CFCs was destroying the earth's ozone layer. Halons used as firefighting agents share the same chemical structure, but include bromine in place of some of the chlorine atoms. Since bromine is a more potent depletor of ozone in the stratosphere than chlorine, halons have Ozone Depletion Potentials (ODPs) much higher than the CFCs. ODP is the measure of how efficiently a compound destroys ozone. The remaining elements in the halogen family are fluorine and iodine. Fluorine has not been found to deplete stratospheric ozone. Iodine is not of significant concern because it has not been widely used due to its toxicity.

131. By the 1970s, large segments of the international community had become dependent on the continued availability of these chemicals for a wide range of industrial processes and products. The broadest use included aerosol propellants for the pressurized dispensing of consumer and commercial products. In the military, CFC compounds had become universally accepted and used in specifications, standards and designs for virtually every weapons system. Halons gained particularly wide use by the armed forces of most NATO nations for firefighting. The civil aviation industry had also become dependent on halons for use on board aircraft. In fact, it is not possible at this time to obtain a certificate of airworthiness for an aircraft from a regulatory agency that conforms to international standards unless a functioning halon fire protection system is installed on board.

4.1.1. The Montreal Protocol

132. The Vienna Convention on The Protection of the Ozone Layer (22 March 1985) determined that the depletion of the ozone layer could harm both the environment and human health. Parties to the Vienna Convention signed an accord whereby they accepted an obligation to introduce adequate measures to protect human health and the environment from the harmful consequences caused by the depletion of the ozone layer. Subsequent to this, the Parties have reached an agreement specifying reduction goals for fully halogenated CFCs and halons (Montreal Protocol: 16 September 1987). This treaty established specific reductions in the production and consumption of ozone depleting substances (ODSs).

133. Production of Ozone Depleting Substances was defined as:

> The manufacture of a substance from any raw material or feedstock chemical excluding the manufacture of a substance that is used, entirely consumed or destroyed in the manufacture of other chemicals, or, the reuse or recycling of an existing substance.

134. Consumption of Ozone Depleting Substances was defined as:

> The amount of the ODS substance produced, plus the amount imported, minus the amount exported to parties to the Montreal Protocol.

135. The Montreal Protocol also contained provisions for continued scientific research on the ozone layer, assessments of the economic and technical feasibility of alternatives to the use of ODS, and periodic meetings of the Parties to determine whether the control provisions in the treaty were adequate to protect the ozone layer. As a result of these features, the Montreal Protocol has been revised several times. The status today is that consumption of halons by developed countries ended 1 January 1994, and consumption of CFCs, methyl chloroform and carbon tetrachloride ended on 1 January 1996. Russia continues some production of CFCs in violation of the Protocol, and has requested assistance from the Parties to resolve this situation. Developing countries have a 10-year grace period in which to comply. Two such nations, India and China, continue to produce CFCs and halons. A multilateral fund has been established to assist developing countries with the incremental cost of conversion to non-ODS technologies.

136. Recently adopted under the Montreal Protocol is an agreement to phase out hydrochlorofluorocarbons (HCFCs) by the year 2030 because these substances have

some ODP. The European Union (EU), however, has called for a more rapid phase out of HCFCs.

137. Alternatives to HCFCs are becoming commercially available as refrigerants. Whereas (blends of) HCFCs could be used as the longer term substitutes for existing equipment and retrofit purposes, non-fluorocarbon cycles may also form an alternative in selected cases for new equipment.

138. Current HCFC-based streaming agents are considerably less effective on a weight and volume basis when compared to Halon 1211. The HCFC alternatives to Halon 1211 have not found wide acceptance for use in portable fire extinguishers to date. The EU banned the use of HCFCs as firefighting agents effective 1 January 1996.

139. Many of the alternative technologies developed by military organizations have been adopted by industry, and others were developed through collaborative efforts between the military and industry. The balance of this chapter focuses on the areas of firefighting agents and refrigerants; solvents are addressed only briefly here. On the latter, see Chapter 5, which is specifically devoted to solvents and volatile organic compounds.

4.2 DEVELOPMENT AND IMPLEMENTATION OF ALTERNATIVES

140. Across all industrial sectors affected by the ODS issue, few true "drop-in" replacements (those without equipment redesign requirements) for these chemicals have been found. While many alternatives include chemical replacements, equipment modifications and the attendant capital expenses have been necessary to implement such replacements.

141. In addition, halons and CFCs have been quite versatile, performing adequately in a wide variety of tasks. As a result, each alternative technology must be evaluated for each application on a case-by-case basis. For example, halon 1301 is used as the fire protection agent in aircraft engine nacelles and in cargo bays. Some of the alternatives under consideration for use in the engine compartments are toxic, which may be acceptable since there is small likelihood of human exposure. Unless separable air control and circulation systems were provided for the cargo compartment, the substitute would be unacceptable because the new toxic agent could migrate into the passenger compartment. In general, the alternative agents tend to have a narrow spectrum of operational effectiveness. Many of the more successful alternative agents have not been chemical replacements, but rather a different process, technique or technology. For example, water mist is being vigorously explored for use in shipboard machinery spaces in lieu of halon 1301 total flooding systems.

4.3 REGULATIONS CONTROLLING ODS IN NATO COUNTRIES

142. While the provisions of the Montreal Protocol apply to all Parties that have ratified that treaty, individual Parties are free to issue their own regulations implementing the Protocol. This has resulted in a variety of control strategies that have the potential of affecting the deployment, operation and maintenance of the military equipment from one country when being used in another. In addition, the European Union ratified the treaty that is binding on EU members. Table 4.1 provides an overview of the control provisions of the Protocol for various Parties.

Table 4.1. Consumption Phase Out Dates for ODSs

	Fire Suppressants	Refrigerants	
	Halon	CFC	HCFC
Montreal Protocol Including Vienna Amdt (1995)	1 Jan 94	1 Jan 96	1 Jan 2020 Service until 1 Jan 2030
EC (1994)	1 Jan 94	1 Jan 95	1 Jan 2000
Germany	1 Jan 92	1 Jan 95	1 Jan 2000
Netherlands	1 Jan 94	1 Jan 95	1 Jan 2000
Spain	1 Jan 94	1 Jan 95	
USA	1 Jan 94	1 Jan 96	1 Jan 2020
Canada	1 Jan 94	1 Jan 96	1 Jan 2020

143. The Montreal Protocol includes provisions to allow limited consumption following the phase out dates for approved essential use requests. These requests are reviewed by the Technology and Economics Assessment Panel of the Montreal Protocol, and either recommended or not recommended for approval by the Parties. To date, very few essential use exemptions have been granted by the Parties. It is important to note that national security functions are not exempted from the terms of the Montreal Protocol. Each application is reviewed individually for essential use as submitted to the Parties for consideration.

144. Under the Montreal Protocol there is no restriction on international trade in recycled halons or CFCs; the Protocol controls apply only to newly produced ODSs. Under the terms of the Protocol, recycled ODSs can pass between countries unencumbered. As a result, a global market in recycled CFCs and halons is developing. However, although the Protocol does not restrict trade in recycled ODSs, other international laws and

individual country laws and regulations have imposed barriers to trade. For example, the Basel Convention on Transboundary Shipment of Hazardous Materials could impose restrictions on the trade of recycled ODSs between countries.

145. In the fall of 1994, the Halons Firefighting Agents Technical Options Committee made a proposal to the Basel Convention authorities that the Convention clarify the compounds over which they would have jurisdiction by excluding the compounds controlled by the Montreal Protocol. The authorities informally accepted this clarification, but the Parties to the Convention have not yet formally ratified this decision. Also, the United States requires notification to national authorities prior to the importation of recycled ODSs and imposes a tax on both new and recycled ODSs. Additionally, some countries in Europe require that specific applications meet the Montreal Protocol definition of "essential use" before even recycled ODS can be used. The interpretation and application of these differing laws and criteria can and do differ among countries, including NATO countries. In addition, some nations are more liberal than others regarding use of ODS in military systems: such transfers of ODS and rules allowing or restricting specific uses then become a matter between the affected countries. This could affect a military unit operating on foreign soil. NATO may wish to consider formalizing agreement on the use of ODS during joint exercises and operations and for forces stationed on foreign soil.

4.4 APPLICATIONS AND ALTERNATIVES: FIRE SUPPRESSANTS

146. Halons have been widely used by military units and in military systems around the world for a variety of firefighting tasks. These include crew and engine protection in armored vehicles; on board aircraft for engines, crew and cargo compartments, wing tanks, and dry bays; shipboard for engine and communications spaces and flight deck operations; and for selected ground command and control facilities. Alternatives exist for most of these applications, and are being incorporated into new systems. However, in some cases, alternatives do not exist, in others implementing the alternative requires extensive and expensive system modifications, and in others incorporation of available alternatives poses unacceptable risk to the health and safety of personnel and equipment. For example, due to the excessive costs associated with retrofit of existing halon systems, the US Navy has decided to except much existing critical shipboard equipment to the end of its useful life. In another case, the Netherlands has determined that the high level of risk to personnel and equipment associated with use of available halon alternatives on existing systems is unacceptable, and will also be vintaging existing systems.

147. Each application must be evaluated individually to determine whether an alternative is appropriate. In some cases, large investments would be necessary to eliminate relatively small quantities of halon, while in others, large quantities might be eliminated with

relatively small investments. Some uses are also more critical than others. For example, aircraft engine nacelles, and shipboard machinery and electronics spaces are all highly integrated systems and substantial modifications would be necessary to change fire protection systems. Many of these critical applications are also critical to survivability in combat. A solution that "buys time" to identify, develop and implement alternatives is "banking," or establishing reserve quantities to service existing systems until the end of their economic lifetime. These reserves are being created in a number of countries, mainly from recycled halons that are removed from systems being retired from service.

148. Some alternatives that have been considered as possible halon replacements include newly commercialized chemicals such as HCFCs, hydrobromofluorocarbons (HBFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). Each of these has some environmental drawbacks, and does not generally perform as effectively as halons. HBFCs have Ozone Depletion Potentials higher than allowed under the Protocol; as a result they never became commercially viable. PFCs have extremely long atmospheric lifetimes, on the order of thousands of years, and are some of the most potent greenhouse gases ever developed. The United Nations Environment Program 1994 Halons Fire Extinguishing Agents Technical Options Report cautions that these should not be used indiscriminately, or in preference to other fire protection systems. HFCs are also global warmers, but not nearly on the scale of PFCs, and their atmospheric lifetimes tend to be relatively short. HCFCs have some Ozone Depletion Potential, on the order of one hundredth that of the halons. But these too will be phased out under the Montreal Protocol by the year 2030. The EU has called for an even more rapid phase out, and there will be many opportunities to amend the Montreal Protocol before 2030.

149. The use of HCFCs as firefighting agents is banned in the EU; however, HCFCs are being considered as alternative clean streaming agents elsewhere. Much of the debate over streaming agents revolves around the need for an agent that is clean or leaves no residue. If some residue can be tolerated, then dry powders are actually much more effective agents than the halons in most situations. The only traditional agent that leaves no residue is carbon dioxide. However, it must be stored at much higher pressures than the halons or other gaseous alternatives, which increases the size and weight of the storage cylinders; also, it requires about 7 or 8 times more agent than halons, making it an impractical solution for many applications. In addition, unlike halons, carbon dioxide is fatal to humans at concentrations required to extinguish a fire in a total flooding situation. Carbon dioxide is being used in a number of hand-held portable extinguisher applications. Other alternatives include new uses of traditional firefighting agents, such as dry powder, water sprinklers and foams. New innovations such as inert gas generators, which use automobile air bag technology to create an inert atmosphere, and water mist systems have also been developed and are nearing commercialization for some applications.

150. One new development in the area of water mist systems is Impulse Fire Extinguishing Technology (IFEX), an alternative for streaming agents which shoots the water mist directly into the core of the fire rather than spraying water particles over the fire. Much work has been accomplished outside the defence arena; for example, the University of New Mexico Engineering Research Institute (NMERI) has been examining toxicity and stability of agents, fire suppression performance in cup burner tests, byproducts of combustion and atmospheric effects. For more detailed information on alternative agents and technologies, see the UNEP report of the Halon Fire Extinguishing Agents Technical Options Committee, December 1994.

4.4.1 Aircraft

151. The requirements for fire protection systems on board civil aircraft are closely regulated by national and international regulatory bodies and by international agreements. Since uses on military and civil aircraft are very similar, military and civil collaboration is accelerating the development and approval process for alternatives.

152. As noted above, aircraft currently use halon 1301 for the protection of engine nacelles, cargo bays, auxiliary power units (APUs), lavatories, dry bays and fuel tanks. Halon 1211 and methyl bromide are also used to protect engine nacelles in the UK. Halon 1211 is also required in hand-held extinguishers in cabin areas. The extent of halon use varies from model to model: US-designed aircraft make extensive use of halon 1301 systems; however, many European-designed military aircraft are fitted with fewer active fire suppression systems, e.g., RAF Tornado aircraft only have one halon 1211 system. Given the wide range of present halon applications, it is likely that a range of substitutes and alternative solutions will be required.

153. An important task group was formed in 1992 to examine the development of alternative technologies and find ways to recycle halon until the new technologies can be introduced. The group was led by The Boeing Co., the Aerospace Industries Association, and the US Air Force and included participation by the International Civil Aviation Organization (ICAO) and aircraft and halon systems manufacturers. The objective is to speed the approval and commercialization of systems that can result in aircraft obtaining certificates of airworthiness, without the use of halons. As noted above, an aircraft cannot obtain such a certificate without halon suppressants at this time.

154. The US Air Force, the US Army, the US Navy, and the US Federal Aviation Administration (FAA) are engaged in an extensive research program to evaluate alternatives to halon 1301 for use in engine nacelles and dry bays. An extensively instrumented jet engine nacelle mockup has been placed in a wind tunnel at Wright Patterson AFB in order to simulate engine fires under flight conditions and test various

agents and discharge configurations. Similar work is going on elsewhere. Based on the results of such experiments, C_2HF_5 (HFC-125) has been selected as a gaseous alternative for engine nacelle fire suppression systems in new aircraft systems. However, there appears to be renewed interest in CF_3I (Halon 13001) by two of the USAF aircraft program offices. It appears to extinguish fires at lower concentrations than HFC-125, which improves both space and weight characteristics. More detailed toxicity, stability, performance, corrosion and atmospheric tests are in progress or planned by various agencies. Toxicity is a concern with this material, and it is not appropriate for use in occupied areas, or areas likely to be occupied. Approval from the US Environmental Protection Agency (EPA) is pending. The first production aircraft likely to use compounds other than halon are the USAF F-22 and the US Navy F/A-18E/F and the V-22.

155. The US Air Force has also conducted extensive tests on full-scale dry bay mock-ups. The halon alternative selected for dry bay fire/explosion suppression systems is also HFC-125. The joint US military and FAA Program for both engine nacelles and dry bays are currently developing design equations to assist in sizing fire suppression systems using the alternative chemical.

156. Certain high performance USAF fighter aircraft use halon to create an inert atmosphere in the fuel cells to prevent explosion in the event the cells are hit by enemy fire. The halon is used to pressurize the cell, and the halon is slowly released over time to maintain pressurization. This is a particular problem with the F-16 because of the large size of the global inventory of these aircraft. The F-117 also uses this system, but there are relatively few of these aircraft in existence. The US Navy A-6 uses halon 1301 for fuel tank inerting, but this aircraft is planned to be retired over the next several years. An alternative for new aircraft is the On Board Inert Gas Generating System, or OBIGGS. This is used in the F-22. The bleed air from the compressor is forced through a series of filters that extract nitrogen and oxygen. The nitrogen is fed into the fuel cells, and the oxygen is used by the crew for breathing. Since there is a continuous flow of nitrogen as long as the engines are operating, the OBIGGS operates over a wider portion of the aircraft performance envelope than the halon system. However, the OBIGGS is heavier and takes up more space than the halon system, and is even more extensively integrated into the airframe. As a result, converting F-16 aircraft to use OBIGGS has so far been deemed an impractical solution, primarily due to the cost and complexity of the conversion.

157. In addition to chemical alternatives such as HFC-125 and Halon 13001 (CF_3I) for engine nacelles and dry bays, technologies described including inert gas generation and fine water mist are being examined for possible use in new weapon systems such as the F/A-18E/F and the V-22. Inert gas generation uses pyrotechnically generated devices that release an inert gas mixture of CO_2 and N_2 that extinguishes the fire. Fine

water mist involves high pressure spray of water particles throughout the compartment to physically extinguish the fire.

158. An alternative approach to aircraft fire protection is to design out the requirement for a suppressant. In this context it is interesting to note that none of the Phantom aircraft used by the RAF were ever fitted with engine fire suppressant systems. Fire suppression relied on stop-cocking the fuel at the engine fire-proof bulkhead and letting the fire self-extinguish. It is intended that the production Eurofighter-2000 aircraft will also use this method for engine fire control.

159. Fire protection in "cargo bays" is still a topic of controversy. Some aircraft cargo holds are protected with halon 1301 total flooding systems, and others are not. In the US Air Force for example, some models of the C-5 and certain C-141 aircraft have halon systems protecting the cargo compartments, while others do not. The C-17 does not use halon to protect the cargo bay. As noted above, alternatives under evaluation by the FAA and other regulatory bodies include water mist, inert gas generators, and non-halon gaseous agents.

160. The alternative for lavatory bottles has been selected by the task group, and is FM-200, or HFC-227ea. International approval of these alternatives by flight certification authorities is expected to occur quickly.

161. Hand-held portable extinguishers containing halon are specifically required for flight certification. This is a relatively small use, but extremely important to the aviation industry. Work is underway within the task group to address this problem, but no alternatives have been forwarded for approval by certification authorities. In December 1995, the UK Civil Aviation Authority published a series of test protocols that move the processes of finding an alternative forward (CAA Paper 9501.3). Both the US Navy and US Army have made a decision to switch from 1301 to carbon dioxide portable extinguishers in their aircraft.

162. Halon 1211 is still used extensively in wheeled portable extinguisher units for protection of aircraft on the ground or on aircraft carrier flight decks. The wheeled halon 1211 extinguishers are kept ready by the ground crew during engine startup for most aircraft. If the pilot or the ground crew receives any indication of a fire (including false alarm indications), the ground crew streams the halon 1211 into the intake of the engine. If this occurs as a result of a false alarm no damage is done by the halon 1211 and the aircraft can be returned to service fairly quickly. If done with a dry chemical (dirty agent), then the belief is that the engine may require tear-down and cleanup, thus costing money and taking the aircraft out of service. However, no tests or studies have been conducted to determine the cost or operational impact of using dry powder for this application. The US Army has

moved to dry powder for their aircraft operations as have a number of civilian airports. Many civilian airports have used dry powder for many years, never having made the transition to halons.

4.4.2 Tactical Vehicles

163. Halon systems are used to protect crew and engine compartments of many types of tactical vehicles. The automatically operated crew system discharges halon 1301 within milliseconds of an incident, flooding the personnel compartment(s). Unless a crew member is actually hit by an incoming round, the crew will survive using this system. To date, no alternative has been identified that can react as rapidly and assure protection for the crew. However, it has been determined that many alliance nations do not employ this system and only use hand-held portable extinguishers for crew compartment protection. Research is now underway at US Army laboratories and elsewhere to identify alternatives to halon 1301 used in both engine compartment fire suppression systems and crew compartment explosion suppression systems.

164. Other alternatives that have been considered for use in engine compartments include powder packs of agent that would burst, and alternative gaseous agents. However, space and delivery system redesign are significant considerations. The primary concern for crew compartment systems is finding a delivery system that can discharge the new agents fast enough to extinguish the fire ball, while not killing the crew from over pressure created by the agent discharge, or chemical toxicity inside the compartment. Tests using instrumented crew compartments have already determined that the explosive discharge of any of the new gaseous agents at minimum will damage the eardrums of the crew.

4.4.3 Shipboard

165. Halon 1301 total flooding systems are used on board ship to protect machinery spaces, gas turbine and diesel engine modules, flammable liquid storage areas and command and control centers. Space and weight are also limitations on ships, due to the extensive integration of systems and large amount of equipment densely packaged onto a warship.

166. The US Naval Research Laboratory (NRL) is continuing research to improve HFC-227ea (FM-200) systems. The US Navy has recently adopted the use of HFC-227ea to protect the main machinery areas of the LPD-17 and CVN-76, whereas the British Royal Navy is specifying carbon dioxide for its new helicopter carrier. None of these solutions are ideal and both navies are carrying out trials on water mist protection, which is especially effective against liquid fuel fires. This work is promising, but results

indicate that such systems will have to be individually designed for the particular hazards and obstructions in the space to be protected; this implies a high cost solution. Water mist may also have promise for the protection of gas turbine and diesel modules. The current research work holds some promise for new vessels. However, few satisfactory solutions are available for retro-fitting or backfitting existing fleets.

167. Depending on when designs for LPD-17 have to be finalized, that vessel is likely to have both HFC-227ea and water mist systems on board. Water mist would likely be used in main and auxiliary engineering spaces, and HCF-227ea would be used in other auxiliary spaces. If testing, which is just beginning (Winter 1996) on ex-Shadwell, is successful, there is also a possibility that LPD-17 or some future ship design could have a combined water mist and HFC-227ea hybrid system in the main and auxiliary machinery spaces.

168. Norway and possibly other Scandinavian countries are planning to use foam systems for Halon 1301 replacement.

4.4.4 Facilities

169. Halon uses at military facilities are comparable to that of the civilian community: halon 1301 in total flooding systems, and halon 1211 in portable fire extinguishers. Selection of alternatives typically follows industry engineering practices. For the majority of total flooding cases, water sprinkler systems (wet or dry) are the primary alternative. Alternative agents or technologies are normally only considered where irreparable damage to the contents of the protected area would be caused by water even after the fire is extinguished. Halon 1211 portable extinguisher alternatives are available with selection of agent dependent upon where the extinguisher will be located and the fire hazard of the area. In many countries, the halon used to protect facility equipment will be recovered, recycled and reused to support the continuing operational needs of weapons systems.

4.4.5 Future Availability

170. For the foreseeable future, aircraft systems, some shipboard systems and tactical vehicle crew compartments will be dependent on recycled halon from existing stocks. For future servicing of these systems, an international market in recycled halons has emerged. Many countries have established halon banks, either as government entities, private companies or public/private partnerships. Several NATO countries have established specific reserves for the military. Lists of these national banks are included in Appendix C of the December 1994 Report of the Halon Fire Extinguishing Agents Technical Options Committee.

4.5 SUMMARY OF HALON ALTERNATIVES

4.5.1 Chemical Replacements

171. A number of halon alternatives are being tested for both aircraft and ground applications. In the US, the EPA is administering a Significant New Alternatives Policy (SNAP) under the provisions of the Clean Air Act. Under this rule, fire extinguishing agents will have to be approved and included on the SNAP list. The agents must not exceed the criteria for Ozone Depletion Potential and toxicity. Global warming is also a basis for limiting the end uses for specific chemicals for specific applications. A summary of these chemical replacements is provided in Appendix H in the document entitled Technical Data and Information: Appendices to LTSS/44 Report.

4.5.2 Not-In-Kind Alternatives

172. Not-in-kind alternatives include systems that use "natural" materials as working fluids, such as ammonia, carbon dioxide, hydrocarbons or water; non-traditional thermodynamic cycles, such as Stirling and Joule cycles; and systems that do not make use of working fluids in the traditional sense, such as absorption, magnetic cooling and thermoacoustic cooling. None of these not-in-kind alternatives have been sufficiently developed to be feasible for use on shipboard in the near term. A more detailed description of these alternatives is contained in Appendix I.

4.6 APPLICATIONS AND ALTERNATIVES: REFRIGERANTS

173. Refrigerants are widely used in military facilities, in ships, aircraft, vehicles and for a variety of other uses. The working fluids used have typically included CFC-11, CFC-12, CFC-114 and CFC-115; the CFC blends 500, 502 and 503; and HCFC-22. The use of CFC-114 as a refrigerant has almost exclusively been confined to military applications and is particularly suitable for use on submarines. Refrigerants have been used for three main applications:

A. For refrigeration purposes, particularly for the storing of foods, medicines, chemicals and organic substances, and for the storage of film and photographic supplies;

B. For air conditioning and cooling, including systems used in tactical vehicles and aircraft for crew comfort and to cool computer and electronic systems; and,

C. To provide chilled water to keep shipboard electronics, missile fuels and health care systems working at optimum temperatures.

174. This section concentrates on the use of refrigerants for shipboard uses, since this is the largest military unique problem. Several NATO countries have included refrigerants in military ODS reserves (or "banks") to assure future operability of military shipboard refrigeration systems still dependent on ODS for their operations.

4.6.1 Shipboard

175. In terms of installing substitutes, there are two types of efforts under way: retrofitting or backfitting existing systems and developing new systems. This section is divided into 3 categories: (a) substitutes for CFC-12 on existing ships; (b) substitutes for CFC-114 on existing ships; and (c) development of new systems for future ships.

4.6.1.1 CFC-12 Substitutes

176. Most navies use CFC-12 for air conditioning on smaller ships and for a refrigerant on all ships. CFC-12 is used widely in the commercial arena and the military was therefore able to make use of work also being done in industry when considering HFC-134a as the substitute.

177. For ship systems using CFC-12, the substitute of choice is HFC-134a. Its advantages are: an atmospheric lifetime of 12 years (compared to 111 years for CFC-12) and zero ODP. Other substitutes that were considered are HCFC-22 and HCFC blends. HFC 134a is expected to be widely available commercially for the foreseeable future. HFC 134a is the refrigerant chosen by US automobile manufacturers to replace CFC-12 in automotive air conditioners after the 1993 model year. Fortunately, modifications for retro-fitting existing systems with HFC-134a are relatively easy to do. The modifications required are:

A. Air conditioning retrofit: lubricant change, dehydrator replacement, control system modification and other minor modifications; and

B. Refrigeration retrofit: lubricant change, dehydrator replacement, control system modifications, thermal expansion valve, compressor speed change or replacement and other minor modifications.

178. Most NATO navies are retrofitting HFC-134a for CFC-12 in surface ships. Recently built ships use HCFC-22 instead of CFC-12 and the intention is to install new HFC-134a systems in future ships. At present, no satisfactory alternatives are available for retrofitting into HCFC-22 units.

4.6.1.2 CFC-114 Substitutes

179. The US Navy currently uses CFC-114 for air conditioning (with a centrifugal compressor) on larger, newer Navy ships. Prior to the introduction of CFC-114, CFC-11 was used for the same applications. As a result, it is found on older, large US Navy ships such as aircraft carriers, submarine tenders, destroyer tenders, command ships, etc. Since these ships have limited life expectancies, the US Navy has made the decision to continue to use CFC-11 on these ships until they are decommissioned. The primary reason for these systems is not crew comfort, but more importantly to provide the air conditioning necessary on ships to keep mission-critical combat equipment and systems cool enough to operate.

180. The reason CFC-114 could not be "stockpiled" to vintage equipment is that the main commercial use was for manufacturing foam products. This was one of the first commercial sectors to eliminate CFC use, and production of CFC-114 dropped rapidly in response. Naval systems were virtually the only users of CFC-114 as a refrigerant, and represented a negligible percentage of the market for the chemical. In addition, foam blowing was an emissive use, meaning there were no "systems" in the commercial market containing CFC-114 that could be recovered to support naval systems. This is a distinctly different situation when compared with halons or other refrigerants.

181. For ships using CFC-114, the best alternative for retrofitting seems to be HFC-236fa. HFC-236fa has shown good performance and matches technical specifications well, but it requires significant modifications for retrofitting, although less substantial than other alternatives that were under consideration, such as HCFC-124.

182. HCFC-124 was eventually dismissed as an alternative because of its non-zero ODP and future production phase-out, and because it operates at much higher pressures than CFC-114, requiring more substantial equipment modifications.

183. HFC-236ea was ruled out due to incompatibilities with submarine atmosphere control systems and poor demonstrated performance in laboratory test plants.

184. E-134 was ruled out due to instability, incompatibility with submarine atmosphere control systems and difficulty in chemical synthesis.

185. According to the US Navy, retrofitting existing systems to use HFC-236fa will take about 8-10 years. This work has not yet begun, and will probably not begin until about FY 1998. This is therefore a long-term program. Currently, toxicity testing is complete for HFC-236fa, except for "rabbit developmental (reproductive) toxicity" tests. The Environmental Protection Agency approved its use on Navy ships on 19 December 1995. Several chemical companies have indicated that they are looking at HFC-236fa as a

possible commercial product (both for use as a refrigerant and firefighting agent), which would be beneficial in terms of procurement.

186. Retrofit modifications are still being developed to enable the use of HFC-236fa. After they are developed, they will need to be tested, and only then can retro-fitting begin. Modifications for the ships need to be developed so that they cause a minimum of disruption. They will be done while the ships are already in port for other repair and maintenance. A major disadvantage to using HFC-134a is that an entire new plant would be required, which would, in turn, require a major hull cut.

4.6.1.3 New Systems Development

187. Most navies have decided that HFC-134a will be used in future surface ships and submarines instead of CFC-12. Ships requiring air conditioning plants with 125 or less tons of cooling capacity will use twin screw compressors, and ships requiring cooling capacities greater than 125 tons will use centrifugal compressors. The first new US Navy surface ship that will be outfitted with it is CVN-76.

188. Several navies use CFC-12 in submarines and hope to retrofit these systems with HFC-134a. However, very small quantities of HFC-134a can build up and react with the atmosphere treatment system to form hydrogen fluoride. Trials are underway to modify systems to address this problem.

189. The problem of replacing CFC-114 on submarines is particularly difficult because, as with the new ships, most plants have been specifically designed to use CFC-114, and they have also been highly integrated into the weapons platform. However, an additional complication with submarines is that the cooling plants are designed and constructed to minimize their acoustic signature in order to reduce the possibility of being detected by enemy forces.

4.6.2 Aircraft

190. Aircraft systems commonly use CFC-12, CFC-114, or R-500 in cooling applications. HFC-134a has been identified as an alternative to CFC-12 and R-500; HFC-236fa has been identified as an alternative to CFC-114. As is the case with halons, retrofit of existing systems can be cost prohibitive. Some NATO countries will be excepting their equipment while others will retrofit where technically and economically feasible alternatives exist.

4.6.3 Tactical Vehicles

191. CFC-12 and HCFC-22 are used for a variety of air conditioning and cooling purposes in the tactical arena. Ambulances are typically air conditioned to maintain a stable environment during the transport of injured personnel. US Army ambulances with CFC-12 air conditioning systems will be retrofitted with HFC-134a. Many tactical command, control and communications systems are air conditioned to cool critical electronic components. Several choices for substitutes are available, to include retrofit with HFC-134a or other non-ODS refrigerants. Other tactical ODS uses include refrigerants in portable water chillers and a variety of uses in field kitchens. Most of the equipment using ODS within these applications is typically replaced rather than retrofitted due to economic considerations.

4.6.4 Facilities

192. Facilities are facing two specific problems: what to do with existing equipment containing CFCs, and what type of new equipment is best to purchase.

4.6.4.1 Existing Equipment

193. For existing equipment there are three choices:

A. Keep and contain/monitor CFCs until replacement of equipment;

B. Convert equipment to run on HFC (i.e., HFC-134a) or HFC blends; or

C. Convert to run on HCFC (new blends made by duPont, ICI, and others; HCFC-22 or HCFC-123).

194. The first choice has the potential drawback of not having replacement refrigerant available, in case of an accidental leak or loss of refrigerant since CFCs are no longer manufactured. However, some countries are recovering CFCs from retired equipment to service existing CFC-based equipment until the end of their serviceable life.

195. Conversion to HFCs is not always possible due to the higher operating pressure of HFC systems; however, if possible, this is the preferred option. At present, it may be more expensive due to extensive flushing requirements needed to receive new polyester-based oil and the need for new gaskets and seals.

196. Conversion to HCFCs is inexpensive, but the manufacture of HCFCs will be banned by the year 2030 under the Copenhagen Amendments to the Montreal Protocol. Some countries, including European Union members, have accelerated this date to 2000.

Thus, this is only recommended for equipment with a lifetime to match the above phase out date.

4.6.4.2 New Equipment

197. New equipment is commercially available that no longer uses CFC as a refrigerant. These are available with HFC or HCFC; however, HFC is the preferred option due to the HCFC phase out.

4.7 SUMMARY OF REFRIGERANT ALTERNATIVES

198. Refrigerant alternatives can take the form of chemical replacements or not-in-kind technologies. An extensive list of chemical replacements is provided in Appendix J. A summary of not-in-kind technologies is provided in Appendix K.

4.8 SOLVENTS

199. The ODSs primarily used as solvents are 1,1,1 trichloroethane (methyl chloroform), carbon tetrachloride and CFC-113. Specific applications have ranged from cleaning aircraft canopies to highly precise cleaning of complex inertial navigation systems, with tolerances measured in microns. The range of substrates and contaminants they clean also include a wide range of materials. The primary considerations when selecting alternatives include corrosiveness, stability, materials compatibility, cleaning ability, flammability, toxicity and residue. The Montreal Protocol has caused industry to eliminate virtually all ODS dependence in the design of new systems and system modifications. However, existing systems and those in development prior to the agreement to phase out ODS production typically require ODS solvents for a variety of maintenance tasks. As alternative solvents and cleaning agents are developed and demonstrated to be technically and economically viable, they are being adopted for military systems. It is that LTSS/44 will serve to transfer non-ODS technologies across the NATO community. Refer also to Chapter 5 of this study.

4.9 SUMMARY

200. Halon production ended on 1 January 1994 and CFC production ended on 1 January 1996. Significant progress has been made to develop and implement technically and economically sound alternatives to ODS. Industry, the military, and government regulators have worked together both within countries and internationally to share technical and management solutions. Two NATO CCMS workshops on "The Military Role in Protecting the Ozone Layer" provided opportunities to share perspectives on the impact of the Protocol on military operations, management responses, and technical and economic information. Technical and management solutions are being shared and

examined in more detail through longer term initiatives such as the NNAG's SWG/12 and this LTSS/44 study.

201. The uses for ODS are similar throughout NATO, and so are the solutions. Through a combination of technical innovation and management actions, sound strategies have been implemented to comply with the Montreal Protocol. Alternatives for many applications have been identified, demonstrated and are being implemented. However, many existing military systems were designed to be dependent on ODS and will continue to be for the foreseeable future. These include some of the most important uses, such as refrigerants and firefighting agents in tactical vehicles, ships and aircraft. Research is under way to find alternatives for the remaining uses, and most of those are nearing solution. To ensure continued availability of CFCs and halons for some of these remaining uses, many nations have established halon and CFC "banks."

202. The Parties to the Montreal Protocol passed an amendment to allow unencumbered international trade in recycled CFCs and halons for the purpose of allowing Parties to draw on the global "bank" to service critical needs that remain. According to estimates by the Technology and Economics Assessment Panel of the Montreal Protocol, global supplies of halons are expected to last until around 2040, based on their estimates of the amount of halon still installed in systems that will become obsolete and available, and estimated rate of consumption. A number of NATO countries are operating banks. National laws restricting specific end uses of ODSs differ across countries. Because of this, NATO may wish to consider developing an agreement that addresses the sharing of ODS reserves, and clarifying whether any specific uses prohibited by domestic regulations apply to foreign forces.

4.10 MAIN CONCLUSIONS

203. The main conclusions reached by the LTSS/44 Study Group on Refrigerants and Fire Suppressants are:

A. Alternatives for most high use applications have been developed and are being implemented.

B. Practical alternatives for several critical weapons platform applications have not yet been identified.

C. Global supplies of recycled ODS appear to be adequate to service mission critical military needs at this time.

D. Differing national rules regarding import/export and end use of recycled ODSs among NATO countries have the potential to impact exercises and peace-keeping operations of militaries on foreign soil.

4.11 MILITARY IMPLICATIONS

204. The use of alternative agents or technologies for ODS, and the continued use of ODSs in limited critical applications, will have a direct influence on military systems. Areas that are affected are:

A. Military R&D;

B. Training;

C. Operational readiness;

D. Logistics; and

E. Maintenance.

205. Factors that determine the relative size or scale of the impact are:

A. Type of alternative selected (i.e., in-kind or not-in-kind);

B. Availability of recycled ODS; and

C. National laws (i.e., ODS use restrictions, emission regulations, import/export regulations).

4.12 RECOMMENDATIONS

206. NATO members should continue to phase out ODS dependent systems as soon as possible in accordance with national policies and programs. Recycled ODSs from these systems should be used to supply other mission critical platforms where alternatives have not been identified or implemented. For military systems that continue to be dependent on ODSs, NATO militaries should revise maintenance and operational procedures and implement best management practices to reduce emissions and conserve the limited ODS resources available.

207. Since practical alternatives for several critical applications have not yet been identified, NATO should:

A. Provide forums and symposiums to exchange information on alternative technologies to ODSs among NATO nations.

B. Coordinate R&D programs of the different NATO nations to reduce overall R&D cost while increasing productivity. This coordination can occur through existing programs within NATO and also by the promotion of bilateral and multilateral R&D and technical information exchange forums.

C. Technologies that should be investigated under these programs include:

(1) use of passive fire suppression in the design of ships, aircraft, and armored vehicles;

(2) use and optimization of water mist fire extinguishing systems;

(3) use of pyrotechnic inert gas generators and powdered aerosol for fire suppression;

(4) basic research into the understanding of fire and suppression chemistry and into new chemistries and technologies for fire suppression that show potential;

(5) technologies that improve the energy efficiencies of existing vapor compression in order to reduce the total environmental impact of using ODS replacements, including global warming chemicals such as HFCs; and

(6) not-in-kind refrigeration technologies and improvements including thermoelectric, evaporative cooling, desiccant cooling, etc.

D. Support military representation on the UN Technical Options Committees to ensure that the Montreal Protocol Parties continue to be made aware of unique military needs, including the need to allow continued use of recycled ODSs for mission critical systems.

E. Form a Specialist Team under DRG Panel 1 to conduct a one-year project to develop a catalog of national laws and regulations regarding the import, export and end use of recycled ODSs. This catalog is to be used to determine the potential impact of these laws and regulations on military operations and exercises.

CHAPTER 5

SOLVENTS AND CLEANERS CONTAINING VOLATILE ORGANIC COMPOUNDS (VOCs)

5.1 DESCRIPTION OF THE PROBLEM

208. Many solvents and cleaners in use worldwide are also volatile organic compounds (VOCs) — methyl ethyl ketone and alcohols, for instance — that contribute to the formation of tropospheric ozone. Certain volatile organic halocarbons, such as 1,1,1-trichloroethane and CFC-113, contribute to stratospheric ozone destruction, and their production has been phased out under the Montreal Protocol, as discussed in the previous chapter of this report. Still others are toxic, such as trichloroethylene, and can affect human and environmental health if discharged into soil, air or water. There is a need to replace all of these classes of compounds with less harmful alternatives.

209. Ozone depleting substances (ODSs), particularly CFC-113 and 1,1,1-trichloroethane, have evolved as the preferred solvents and cleaners in many applications because of their chemical stability, their relatively low toxicity and because they are non-flammable. Oxygen systems, including life support systems, submarine, aircraft and medical applications, and fire and rescue backpacks have depended on CFC or chlorinated solvent cleaning. Perhaps the most diverse number of applications involve 1,1,1-trichloroethane, which has been used as a "cold solvent cleaner" in the general repair and maintenance of engines, tools, turbines and generators, audio and video equipment, etc.

210. In the face of increasing evidence that CFCs and halons are affecting the ozone layer, the United Nations Environment Program (UNEP) in 1981 initiated the development of international policies to reduce the availability of these substances for use. In January 1989, the Montreal Protocol on Substances which Deplete the Ozone Layer came into effect, and was amended in 1991, 1992 and 1995 to reflect the growing concern over the integrity of the ozone layer. As of February 1994, 132 countries and the European Community — representing essentially all the world consumers of CFCs and halons — had ratified the Protocol.[15]

211. The Montreal Protocol Copenhagen Amendments of 1992 set out the reduction schedules and phase out dates for consumption of CFCs (January 1996). It is

---

15 UNEP 1994 Report of the Solvents, Coatings and Adhesives Technical Options Committee, 1995 Assessment. Kenya, 1994.

important to note that the definition of consumption is based on production balanced by imports and exports. Consumption is not synonymous with use in all jurisdictions; in some cases the use of stockpiled new or recycled ODSs will continue for many years.

212. Hydrochlorofluorocarbons (HCFCs), now in use in some applications as alternatives to CFC-113 and 1,1,1-trichloroethane, are also ozone-depleting substances and are considered to be short-term substitutes; the Montreal Protocol requires that consumption of HCFCs be phased out by 2020.

213. The 1994 Report of the Solvents, Coatings and Adhesives Technical Options Committee itemizes the applications of CFC-113 and 1,1,1-trichloroethane as cleaners, and presents alternatives for reducing or replacing them. Included is a chapter describing case studies of phase-out activities, several of which are in a military context. The UNEP perspective is that there are several solutions to every problem and that it is up to each enterprise, the military included, to decide what is appropriate and applicable for its use.[16]

214. In January 1994, a NATO CCMS meeting entitled "The Role of the Military in Protecting the Ozone Layer" took place. At that time presentations were made indicating there were many technical solutions to the use of ODSs as solvents, and recommending further sharing of information and faster implementation of existing alternatives.[17]

215. The Montreal Protocol is not the only impetus for restricting the use of some cleaning compounds. Many are priority pollutants in one or more NATO countries and their use is being or may be restricted. Problems and costs associated with hazardous waste disposal, industrial hygiene and fire safety concerns may also motivate a change in cleaning technique.

5.2 IMPLICATIONS FOR THE MILITARY MISSION

216. While industry and the military share the same cleaning problems, the military has the unique challenge of dealing with a larger number of cleaning processes under a greater variety of circumstances than most other organizations. CFCs were widely used in the past because they seemed to be so universal, but replacing them requires a wide

---

16 Ibid.

17 2nd International NATO/CCMS Conference: The Role of the Military in Protecting the Ozone Layer, Volumes I and II. Brussels, Belgium, 24-25 January 1994.

variety of alternatives depending on the application. Few industries have as many applications and different types of parts to clean as the military.

217. A solution at one level of the logistics chain is not necessarily desirable at another. This could be due to economic or technical feasibility problems. High capital cost equipment required to solve a cleaning problem at a depot level may not be technically or economically feasible to implement in the field or at locations where the required volume of cleaning is not great enough. Problems that are relatively easy to solve on land may be difficult to solve at sea and vice versa. Smaller forces may not be able to afford some of the technologies that large forces can implement, or the small volume of parts to be cleaned may mean that high capital cost equipment is not cost effective.

218. Field maintenance may be affected by different national regulations for targeted substances, which may mean that a cleaning process acceptable in the home nation may not be permitted in a host nation. Appendix M lists the targeted cleaning substances in Canada, the United States and the European Community.

5.3 ALTERNATIVES AND POSSIBLE SOLUTIONS

219. CFCs have been used as cleaners where cleaning was not required or where other more suitable cleaners were available, simply because they were non-toxic, effective, versatile, readily available, they evaporated fast and they left little or no residue on the cleaned part. Most solvent cleaning applications have unique characteristics that prevent implementation of across-the-board solutions. Even very similar processes often have subtle differences. The difference may be due to part composition, the type of contaminants to be removed, or impacts of previous or subsequent maintenance operations.

220. Pollution prevention for solvents used in cleaning applications can include a process change that reduces or eliminates the cleaning requirement, or that makes the delivery or recovery of the solvent more efficient, resulting in a decreased use of solvent. Substitution of a different kind of solvent is another form of pollution prevention and may also involve a process change. Some problems associated with mitigating pollution problems caused by solvents and cleaners can be minimized by changes in management practices:

A. It should be determined how clean a part needs to be and that part should be cleaned to that level of cleanliness and no further, unless the cleaning system in place makes it more cost effective to do so; the no-clean option should be considered as a possibility. CFCs were in such wide usage in the past that their use formed a kind of cleanliness standard, which was not necessarily required.

B. During a maintenance process, unnecessary cleaning of parts can be avoided by storage of parts so that they do not have to be repeatedly cleaned; for example, they could be stored in their ultimate working fluid. Use can also be made of vapor corrosion inhibitors in the packaging and nitrogen purged plastic bags. Use of different preservatives that are removable with soap and water can simplify field cleaning.

C. The US military has implemented the pharmacy concept, which restricts the availability of ozone depleting substances and other hazardous materials to personnel authorized by maintenance instructions to use them, and limits the amount issued to only that required for the task at hand. This procedure has significantly reduced solvent usage.

221. Solvent alternatives developed to date in anticipation of the phase-out of CFC-113 and 1,1,1-trichloroethane include no-clean technologies, aqueous and semi-aqueous cleaning, other hydrocarbon solvents, HCFCs, non-ozone-depleting chlorinated solvents, PFCs, and non-solvent cleaning processes.[18]

222. HCFCs are last resort substitutes in some applications, due to the upcoming phase out of these substances. These and other halocarbon solvents have an impact on the environment, either as ozone-depleting substances, as contributors to potential global warming, as precursors to ground level ozone or due to their toxicity. Non-halocarbon solvents, such as mixtures of hydrocarbons, are alternatives in some cases, but may have occupational or health hazards associated with their use. Non-solvent cleaning processes include the use of pressurized gases, supercritical fluids, pressurized water jet and media blasting.

223. Ideally, the "no-clean" technologies are now being widely implemented in the electronics manufacturing industry could be adapted to other processes. The second choice in terms of preservation of the ozone layer and protection of the environment in general is aqueous or semi-aqueous cleaning.

224. In general, alternatives to solvents used in cleaning applications must be evaluated for individual applications. Factors such as material composition, geometry and intended use of the part are all critical. Alternatives are currently being tried by some NATO countries with some promising results; examples are described in the remainder of

---

[18] UNEP 1994 Report of the Solvents, Coatings and Adhesives Technical Options Committee, 1995 Assessment. Kenya, 1994.

this section, and details are presented in Appendix L, in the document entitled Technical Data and Information: Appendices to LTSS/44 Report.

225. The following six sub-sections describe the areas of highest solvent usage and some outstanding problems. Other sources of information, as well as a draft standard for selecting cleaning agents, are presented in Appendices M, N, and O.

5.3.1 Wipe Cleaning

226. A typical wipe cleaning operation consists of applying a small amount of solvent directly onto a part or a rag used for wiping the part clean. Often the solvent selected for use evaporates fast, leaving little or no residue. The rapid evaporation rate is a major factor contributing to air emissions. The amount of emissions can be reduced by selecting a solvent with a low vapor pressure, decreasing the amount of solvent used and controlling rag disposal. Training to develop good housekeeping practices and the use of launderable towels for wipe cleaning may also result in decreased use of solvent. Factors to consider in selecting a solvent are its ability to remove the contaminants, material compatibility, toxicity, flammability, vapor pressure and odor. A strong odor, even if it is pleasant, may become an irritant with extended exposure or, conversely, a warning signal of high air contamination.

5.3.2 Precision Cleaning

227. Precision cleaning is a process of cleaning to an established high cleanliness standard. It may require a clean room environment and cleanliness verification. A typical precision cleaning operation was the use of CFC-113 in a cold cleaning bath or vapor degreaser. Alternative technologies being successfully used in some US applications are aqueous ultrasonic parts washers with deionized water rinse, rust inhibitors and a drying cycle, and supercritical fluids. The use of supercritical CO_2 is usually restricted to small parts due to limits on machine design. Volatile methyl siloxanes (VMSs) are being evaluated for use in some US applications where water is not acceptable. VMS solvents have low surface tension and a high evaporation rate.

228. Ethyl acetate is being used at Air Force Plant Fort Worth for cleanliness verification. It has been recommended as a replacement for CFC-113 at this location and is currently available, although further demonstration and validation testing is required. Ethyl acetate removed the contaminants tested at least as well as CFC-113, although it cannot be used on parts contaminated with fluorinated greases. It is cheaper than CFC-113 and no additional equipment or disposal costs are anticipated. A disadvantage is the flammability of ethyl acetate and the possibility of respiratory irritation; a fumehood is recommended to reduce this hazard.

229. Supercritical carbon dioxide degreasing has great potential for use on high value precision parts, although the capital cost and low throughput may limit its use for other applications. Also, some soils are not soluble in supercritical CO_2 and particulates are more difficult to remove this way. In the long-term, solid state metal cleaning may be a useful technology, but it may be constrained by part geometry.

5.3.3 Cold Cleaning and Degreasing

230. Cold cleaning is usually immersion of the part to be cleaned in a room-temperature solvent bath or the vapors of that liquid (at a temperature below the boiling point), often accompanied by some form of agitation (spray, mechanical or ultrasonic). In the past, a relatively large volume of solvent was used because there was usually no vapor level control on the equipment, and often there were many cleaning stations, each containing frequently changed solvent charges.[19]

231. To aid in the general reduction in VOC use, cleaning stations that are designed to collect solvent vapors for recycling can be used. In addition, the use of low vapor pressure solvents such as aliphatic petroleum hydrocarbons, esters, terpenes and blends of these substances are also being used to reduce VOC emissions.

232. In studies carried out at the Engineering Propulsion Laboratory at Air Force Plant Fort Worth, over 60 cleaners (Appendix L) were evaluated as possible replacements for ozone-depleting solvents in mechanical cleaning operations. The preferred replacement, a hydrocarbon cleaner, met all technical requirements and is readily available.

233. Ultrasonic aqueous degreasing of aircraft wheels and brake assemblies is being demonstrated, and a commercially available system to remove carbon deposits in preparation for non-destructive testing is to be demonstrated at Canadian Forces Base Trenton.

234. In the UK, materials testing programs have been set up to evaluate alternatives for these controlled substances. Alternatives identified so far include: low VOC solvents with low toxicity, such as aliphatic hydrocarbons in commercially available cleaning products; aqueous and semi-aqueous solutions; and aqueous/media blasting technologies.

---

19 Ibid.

5.3.4 Vapor Degreasing

235. Vapor degreasing involves immersing parts into the hot vapor of a halogenated solvent, where the part is cleaned by the condensing vapor. Even with vapor control, there were still large solvent losses from this kind of equipment.

236. Aqueous cleaning is generally the most desirable alternative, if it is considered acceptable for the specific application; that is, the part must be water and additive tolerant. Flash rust and water entrapment are often concerns, and surfactants, saponifiers, anti-foaming additives and drying cycles may be required. Aqueous parts washers using alkaline detergents are quite common now at most US DoD depot and intermediate maintenance facilities as replacements for vapor degreasing. These parts washers have replaced the vast majority of vapor degreasers for general metal cleaning operations. Some of these are now being installed on larger US Navy ships. Pre-cleaning steps to remove heavy soils are important to avoid excessive contamination of the part washing solution, and post-treatment such as rinsing and drying, are important parts of these aqueous processes.

237. Semi-aqueous cleaners, thermal cleaning and hermetically sealed vapor degreasers are other alternatives to traditional vapor degreasing.

238. A system is available now in the United States that replaces 1,1,1-trichloroethane in the cleaning of jet engine components. It consists of a power spray wash with an aqueous alkaline solution followed by a rinse with deionized water and drying with forced hot air. Several options have been tested that would minimize the rinse waste water:

A. A closed loop can be created for the rinse water, using an in-line filtration system consisting of UV treatment, carbon filter and two ion exchange beds. This option requires that the rinse reservoir be changed periodically.

B. A second option is to use a low pressure evaporator either with a cooling tower or with plant water to provide cooling water for the condenser.

C. A third option is ultrafiltration using ceramic membranes to separate out the oils and cleaning solution while the clean permeate returns to the rinse reservoir.

239. An ultrasonic degreasing process has been in place for 2 years at Canadian Forces Base Halifax, replacing CFC-113 to clean reusable marine engine filters. The replacement was motivated by large solvent losses that were occurring from the vapor degreasing unit that was in place. Four possible alternatives were examined: sealed

equipment; non-chlorinated solvent systems; semi-aqueous systems; and aqueous systems, either as immersion, spray or ultrasonic processes. An aqueous ultrasonic system was eventually chosen: a mildly alkaline solution is used and oil is skimmed off the water surface. The sealed equipment was considered expensive and unnecessary; semi-aqueous systems posed a potential fire hazard; and non-chlorinated solvent systems would have required the use of a solvent with a flash point above $60^{o}C$ ($140^{o}F$) in order to meet base fire regulations. The parts to be cleaned are corrosion resistant and contain many small pores, which made an aqueous ultrasonic system attractive.[20] Existing systems can be refitted to accommodate this process. Similar results have been realized in the United States at Corpus Christi Army Depot.

240. An aqueous spray was found to be superior to immersion cleaning for solid rocket motor metal components. The Thiokol Corporation reports that of more than 150 spray cleaning processes tested, two performed particularly well, producing greater adhesion than with 1,1,1-trichloroethane vapor degreasing. Further validation testing is needed in order to develop ways to control foaming in the spray cleaning process before this technology is ready to be implemented.

241. In the UK, the cleaning of components by vapor degreasing with 1,1,1-trichloroethane is now being replaced by ultrasonic processes using either aliphatic hydrocarbon solvents or biodegradable aqueous cleaners. If vapor degreasing is essential, then trichloroethylene could be used in closed systems, although due to its toxicity this is not desirable.

242. Longer-term possibilities currently being researched involve the elimination of not only the hazardous solvent but also wastewater streams generated by aqueous alternatives. The principal technologies are: laser-based, solid state and supercritical carbon dioxide cleaning systems.

243. A laser-based cleaning system that removes contaminants without generating a wastewater stream has been funded for technology demonstration and is scheduled for implementation in the United States by 1997. This technology will be applicable to aircraft and general equipment cleaning and coating removal, will eliminate the use of solvents and is expected to be cheaper than traditional vapor cleaning methods. It is considered unlikely that it will be acceptable, however, for general cleaning of parts that may have complex geometries or blind holes.

---

20 MCF Newsletter, Environment Canada. March 1995.

5.3.5 Cleaning of Electronic Equipment and Printed Circuits

244. There are several cleaning operations associated with the manufacture, maintenance and repair of electronic equipment. They include circuit board cleaning, conformal coating removal, flux removal, and the cleaning of electrical contacts. Such factors as circuit board construction, component compatibility, and types of coatings are critical in selecting a cleaning process. There exist some new "no-clean" technologies using either flux-less solder or low solids fluxes. They are being evaluated and implemented in selected areas as compatibility and reliability issues are being resolved. For example, the following technologies have been successfully used in some US applications: aqueous spray with detergent; 2-propanol (isopropyl alcohol), deionized water and nitrogen blow dry; detergent solution followed by deionized water rinse and air dry; and terpenes.

245. A solvent blend, consisting of d-limonene and aliphatic hydrocarbons, has been evaluated as a replacement for 1,1,1-trichloroethane for the cleaning of electrical equipment, and is being adopted by some units of the US DoD.

246. Another system consisting of a biodegradable aqueous cleaner followed by either a hydrocarbon cleaner or a water rinse and a drying step is now being used for a variety of precision cleaning applications including computers, aircraft instruments, telecommunications equipment and photographic equipment. The cleaner performs best when it is heated, and in most cases the aqueous cleaner alone, followed by a water rinse, provides a satisfactory result. For more demanding requirements, one or more rinses with the hydrocarbon cleaner is required. This method is also being used in combination with ultrasonic cleaning, which reduces the cleaning time.

247. In the Netherlands, either methylene chloride or 1,1,1-trichloroethane is currently used for cleaning printed circuits. Both Lufthansa and KLM airlines have identified the use of ethanol as an alternative for cleaning printed circuits. Lufthansa uses pulped walnut hulls for the stripping of printed circuit boards; KLM cleans with ethanol, strips with methylal (dimethoxymethane, which has the drawback of being very volatile). In these processes, training is more important than it has been with previous methods.

248. In the UK, aliphatic hydrocarbon is being used to replace 1,1,1-trichloroethane for cold cleaning applications on electrical equipment. A water-based biodegradable solvent cleaner is being considered for cleaning printed circuits. A mixed hydrocarbon and alcohol solvent-based product is being used for stripping conformal coatings. Fire codes of different countries may, however, preclude a universal application of this procedure.

5.3.6 Cleaning of Oxygen Systems

249. There are several types of cleaning operations associated with oxygen systems, and a "drop-in" replacement has not been found for CFC-113 in all oxygen cleaning applications. Oxygen systems consist of tubing, gauges, regulators and valves, which may require cleaning because of the danger of ignition of organic contaminants. It should be stressed, however, that the need to clean these components is a matter of some debate. The cleaning system must be capable of removing organic soils, dust and metal fines; it should be non-toxic, non-flammable and it must lend itself to cleanliness verification.

250. The US Navy has developed the Navy Oxygen Cleaner (NOC), which consists of a wash with an inorganic alkaline solution followed by a water rinse. The cleaning system removes particulates, oils, greases and fats, and fluorinated oils and greases from metallic, plastic and rubber surfaces. This cleaner, diluted by 50 percent, is being used in some US activities to clean open-ended tubing and components where entrapment of the cleaner is not a problem. HCFCs, such as HCFC-225 and HCFC-141b, are being evaluated for use on gauges and components where solvent entrapment is a concern, until a more acceptable solution can be found. Use of HCFCs is not a long term solution since these compounds themselves are due to be phased out, and cleaning with them requires controls due to toxicity concerns. The new HFCs and Hydroflouroethers (HFEs) are being evaluated as potential long term solutions but may be more expensive. Perchloroethylene is still being used in many countries but its replacement is strongly urged due to toxicity problems.

251. In the Netherlands, a liquid emulsion cleaner in deionized water is used in an ultrasonic bath to clean oxygen system components, followed by a half hour in warm to hot deionized water in an ultrasonic bath, followed by an ethanol rinse and oven drying in air.

252. In the UK, trials have been carried out on a number of replacement materials and systems for cleaning to "oxygen-clean" standards. These trials include an evaluation of an isopropyl alcohol and perfluorocarbon mixture vapor system and the US Navy Oxygen Cleaner. However, none of the processes under trial were found to be totally satisfactory for UK applications. Further work is planned using various combinations of a hydrocarbon cleaner and aqueous cleaning products.

253. Atomic oxygen cleaning, a process that uses low temperature atomic oxygen plasma to clean oxygen system components and piping, is under development.

5.4 CONCLUSIONS

254. The LTSS/44 Study Group on VOC solvents and cleaners reached the following conclusions:

A. Each application has unique characteristics that prevent implementation of across-the-board solutions; however, solutions exist for most applications.

B. There is no agreement on the requirement for cleaning and no agreement on the cleaning process to be used for oxygen systems. The requirement for cleaning needs to be rationalized and more information is needed about the health and safety aspects of the cleaning technologies.

C. There is a requirement to eliminate toxic solvents used for cleaning in confined spaces and to replace emulsifying degreasers for bilge and ship tank cleaning. Further research should be carried out in these areas.

D. Some cleaning operations are not necessary and in others the degree of cleaning is excessive. The degree of cleaning required should be determined for each application, and proper handling and storage practices put in place to avoid unnecessary cleaning.

5.5 RECOMMENDATIONS

256. Based on the research and analysis conducted by LTSS/44 on VOC solvents and cleaners, two specific recommendations are offered:

A. A database of case studies and solutions, standard test procedures and test results should be made available to all nations, in order to facilitate the sharing of information and reduce duplication of effort. There are many case studies available and electronic databases already in existence that could form the basis of this database.

B. Further research is required to determine alternative cleaning processes for specific applications in confined spaces on board ships and submarines.

(This page is intentionally blank)

CHAPTER 6

SURFACE PREPARATION AND COATINGS

6.1 SUMMARY

257. The processes used to apply organic and inorganic surface coatings to military equipment produce a significant environmental impact. Throughout the life of the equipment, the following cycle repeats itself: surface preparation, coating application and finally, coating removal. Each sequence involves the use and release of hazards in the form of heavy metals and volatile organic compounds (VOCs). To comply with national legislation and international agreements, the NATO alliance members must take appropriate action to prevent release of these hazards into the environment without significant sacrifice to the military mission. This study has identified significant activity directed towards: the elimination of heavy metals and VOCs for surface preparation and coating systems, and the use of non-chemical coating removal methods. The efficiency of coatings transfer processes were also determined to be in need of significant improvement.

258. Much research and development work remains to be completed. This study recommends that the following surface preparation and coating objectives for organic contaminants be addressed:

A. Environmentally compliant coatings with longer lifetimes than existing VOC based coatings;

B. High efficiency spray equipment;

C. Non-toxic antifouling coatings;

D. Non-chromated corrosion inhibiting coatings for aircraft;

E. Primerless coatings for aerospace and naval aircraft;

F. Non-chromated conversion coatings;

G. Zero-VOC coating systems;

H. Low-VOC coatings applicable in colder temperatures;

I. Low-VOC, chemical agent resistant, corrosion protection, camouflage coating; and

J. Cost-effective non-chemical methods for coatings removal.

259. In the area of inorganic contaminants, this study recommends the following surface preparation and coating objectives be addressed:

A. *Plating Processes* must be modified in order to:

(1) minimize or eliminate heavy metal/hazmat generation;

(2) develop a scrub process to reduce toxicity (in the spirit of pollution prevention); and

(3) develop alternatives to plating processes including both inorganic coatings not applied by electrolytic methods and organic coatings of low toxicity.

B. *Heavy Metal Elimination/Minimization*

(1) alternatives to chromium, cadmium, copper, lead; and

(2) materials substitution (i.e., zinc molybdenum vs. zinc chromate coatings).

C. *Heavy Metal Waste Stream Minimization*

(1) process discharge reductions related to surface preparation;

(2) "clean" abrasive blast media (i.e., specified heavy metal/contamination levels for blast media); and

(3) reduction and/or redirection of plating effluents.

6.2 POLLUTION PREVENTION

260. This chapter on surface preparation and coatings specifically identifies those inorganic and organic compounds that are known pollutants and have contributed to the current restoration problems at NATO military bases. Also described are similar problems encountered aboard NATO ships and in the marine environment. While substantial inorganic and organic contamination is generated from manufacturing and rework operations, only surface preparation and coatings were selected for inclusion in this study.

6.2.1 The Problem

261. This chapter focuses on one area of pollution that results from the military and industrial use of inorganic and organic materials, namely surface preparation and coatings. Surface coating compounds found at military sites originate from chemical deposition processes, paint and paint stripping operations, hot and cold spraying techniques, spray booth operations, marine coating and stripping processes and from electrolytic plating operations. Frequently found inorganic elements and compounds include: cadmium, chromium, copper, lead, mercury and zinc. Organic compounds of tin and copper emanating from hull coatings are found with high relative frequencies in the marine environment. Residual organic compounds originating from surface preparation and painting/repainting operations are found at depots, bases, rework facilities and on ships.

6.2.2 Organic Coatings

262. Organic surface coatings are primarily paints. A paint normally consists of three separate types of components: an organic solvent, also referred to as a VOC; a binder or medium; and a pigment for coloration. Each of these three components can have a significant environmental effect, and much of the work outlined in this chapter aims to minimize this effect. In some cases, the solution to the environmental impact problem is to simply eliminate one of the three components. More often, it is only possible to moderate the environmental impact of the components. Some coatings can have one of these components missing, i.e., varnishes that contain no pigments.

263. The processes used to apply organic surface coatings to military equipment also produce a significant environmental impact. Pre-requisite to painting is the removal of any existing coating, cleaning the surface of the substrate, ensuring the paint is applied as specified, and allowing the paint to dry properly. For new items, this normally involves cleaning a bare metal surface before painting with a primer coat. Metal surfaces are normally protected from corrosion by the use of a thin film of oil. This oil must be removed immediately before painting; the normal method of degreasing is to use a VOC solvent. Chlorinated solvents have been exceptionally useful since they are non-flammable and do not give rise to a metal failure process known as hydrogen embrittlement. Limits on VOC emissions from surface preparation have led to new approaches being developed, which are outlined in this chapter.

6.2.3 Primer Coatings

264. A paint system for a particular substrate normally comprises at least a primer and a top coat. The primer is a special coating is designed to overcome the problems of bonding organic coatings to the substrate, which could be a metal, a ceramic or

another polymer. Chromate coatings have been generally used as primers for aluminum but pose serious environmental problems in their manufacture, disposal and fabrication.

6.2.4 General Surface Coatings

265. Military equipment is usually colored to blend in with its operating environment — green army vehicles and grey ships being the most obvious examples; most military equipment is painted to avoid both visual camouflage, concealment and deception (CCD) and electronic detection. In addition, most equipment is usually painted to provide corrosion protection to the structure. Thus, there is a constant requirement to maintain a high quality protective paint coating on all vehicles and equipment.

6.2.5 Applications/Service Unique Requirements

266. Special surface coatings are more common in defence equipment than in the civil sector, since the former is expected to operate at extreme conditions of weather, temperature and humidity. Each of the three services select and employ their own types of special coatings.

6.2.5.1 Air Force and Aerospace Coatings

267. Military aircraft require special surface coatings that are both resistant to abrasion and erosion, and can be easily removed to allow the airframe to be inspected for corrosion and wear. A range of special aircraft paints, usually based on polyurethanes and epoxies have been developed for this purpose. Camouflage coatings and temporary coatings may also be required for special missions.

6.2.5.2 Navy Coatings

268. Ships require a number of special surface coatings beyond corrosion prevention. The problems of fouling of ships have been known since the Phoenicians developed the first material to inhibit barnacle growth. Anti-slip deck paints, paints with controlled gloss durability, and fire resistance are common requirements. Special noise reduction coatings and tank coatings are also required.

6.2.5.3 Army Coatings

269 Army equipment also requires a number of special surface treatments, such as chemical agent resistance and camouflage. A number of temporary, easily removed finishes are also required.

6.2.6 Inorganic Coatings

270. Certain heavy metals and their salts pose a significant environmental concern as inorganic coatings. The materials are bioaccumulating and environmentally persistent toxins. The relative hazard created by these materials depends on the chemical form and type of application. Materials such as nickel and chromium, when used as plating, pose little problem in their elemental final form. Yet, the plating processes themselves create problems because the electrolytic bath solutions must be treated or recycled. The processes, however, are typically confined to larger production facilities that can handle such recycle/recovery, which field activities could not. Cadmium is unique in that it is a hazard at very low levels of exposure as a solution and as a residue from the elemental form.

271. Hexavalent chromium poses a different and significant environmental problem when used as a conversion coating, sealer, corrosion inhibitor or etchant. These applications are often employed for field level maintenance where disposal techniques are unsophisticated. These (hexavalent) chromium salts result in risks to both personnel and the environment. Trivalent chromium salts are more environmentally benign, but they offer few of the corrosion benefits identified with the hexavalent form.

272. Residue from elemental nickel and nickel salts also poses an environmental risk, but is less toxic and less prevalent than cadmium and chromium materials. Other heavy metals such as arsenic, mercury and lead, although very toxic, find little use within current military activities. Zinc is widely used as a plating or coating in its elemental form and as a salt for corrosion inhibition in coatings. Zinc exhibits the least health and environmental impact and is the most environmentally desirable of the heavy metals where applicable.

273. While new technologies have been developed and demonstrated for the eventual cleanup of previously deposited inorganic contaminants, the most successful approach has been to excavate and remove the offending chemistry to other locations. Previous research by the United States has determined that inorganic elements and compounds in soil, silt and sludge form the most prevalent group of contaminants found at military installations, and are also among the most costly and difficult to remediate.

6.3 IMPLICATIONS FOR THE MILITARY MISSION

274. The NATO military forces create waste streams of inorganic elements (and their salts) and organic compounds as by-products of operations, training and maintenance activities, storage and warehousing, production, testing and evaluation and R&D. Continuing the generation of these pollutants will eventually lead to violations of

national, regional, or local laws and covenants. It is possible that further operations and training could be limited or stopped entirely if the contaminating substances are neither curtailed nor controlled. The creation of international incidents in cross border pollution emanating from NATO operations and exercises could seriously jeopardize the military mission and increase international tensions.

275. The ultimate health impacts and effects on humans, birds, fish and other animals are dependent both upon the toxicological nature of the contaminant and the intensity and duration of the exposure. Common outcomes include skin rash, diminished mental capacity, blood poisoning, birth defects and internal organ failure. Plants may also react negatively to various inorganic substances depending upon the specific soil and moisture conditions.

276. During operations and other training activities it has been determined (from studies in Germany, the United States and Canada) that the soil and ground water have been contaminated with organic and inorganic substances including lead (from industrial and munitions activity and from fuels), nickel and cadmium. Maintenance and storage activities yield waste from paints, paint pigments, sludge, grit from surface cleaning, and from cold metal forming and cutting operations. Additional waste streams of effluents that originate from plating and other electrolytic processes eventually migrate into the water and soil. Heavy metals including chromium, cadmium, lead and nickel are typical of the contaminants found in soils and water, both surface and ground, following prolonged use of a site that was previously dedicated to military maintenance and storage activities.

277. Production processes that include the manufacture and re-manufacture of weapons, explosives, pyrotechnics, rockets, propellants and munitions also create environmental pollution. Cyanides, phosphates, chromium and zinc are found in effluent and as deposits originating from these processes. Energetics also find their way into the waste streams, and many energetic materials are inorganic in nature. Lead and both red and white phosphorous are commonly found at former munitions production sites. Test sites also contain similar inorganic pollutants as well as unexploded ordnance of all types.

278. The VOCs that are used in general surface coatings are now known to contribute to the formation of low-level ozone, which can lead to smog. By deliberate design, the largest single fraction in a can of paint is the VOC, which is deliberately added to evaporate into the atmosphere while providing a suitable thickness of surface coating to dry and protect the substrate. The research challenge is to reformulate paints to provide this thin protective coat by some other means. In order to meet air quality standards in NATO countries, paints are being redesigned to minimize the emissions of ozone-forming solvents. This can be accomplished either by reducing the levels of VOCs to legally permitted values, or by eliminating them altogether. Another approach to voluntary

compliance with air quality standards is to prevent the release to atmosphere of the VOCs by abatement techniques. However, this approach does not meet the definition of pollution prevention as adopted by this study. See Chapter 1, paragraph 7.

279. Historically, the nature of the VOCs used in paints has been determined by the binder for which they act as a solvent. Most paints were made from linseed oil based materials for which the optimum solvent was another natural material, mineral spirits. As paint design has become more sophisticated, so too has the range of VOCs increased.

280. In the move towards non-VOC based paints, or more accurately, environmentally compliant coatings, it has become necessary to examine different chemistries, especially those based on water-soluble materials. The technologies of VOC-based and water-based binders are quite different, which is why it is very difficult to reproduce the same properties from both. One potential long term option is the use of supercritical liquid carbon dioxide instead of the VOC solvents. The same approach can be followed to produce VOC-compliant adhesives.

6.4 TECHNICAL CHALLENGES

6.4.1 Aerospace Coatings

281. Reformulating special aircraft surface coatings to remove their VOCs is especially difficult. The pre-pack materials used to create the coating generally react with water, making it difficult to retain the special properties of the coating system. To some extent the same problems exist for missile coatings.

6.4.2 Navy Coatings

282. The development of self-polishing tributyl tin (TBT) copolymer antifouling paints has meant that a large ship only requires repainting every 5 - 7 years. The slow release of a toxic biocide to eliminate the drag caused by mollusks can damage other marine organisms: this has led to severe limitations in the use of TBT systems. Other systems, based on copper antifoulants, may have less effect on marine life, but may be required to be applied more frequently to achieve the same effect as TBT.

6.4.3 Army Coatings

283. A major problem in the development of compliant coatings for special Army use is Chemical Agent Resistant Coating (CARC). This is used as a camouflage topcoat for US Army tactical equipment and meets current VOC regulations. Further reductions in VOC emission limits will require the development of a water reducible/water dispersible polyurethane polymer coating. Currently, chemical agent resistance is poor in

the alternatives. Other difficulties include high humidity drying problems and cold weather storage stability.

6.5 STATUS OF EXISTING TECHNOLOGIES

6.5.1 Removal of VOC Solvents

284. The United States is working on methods to eliminate the use of VOC solvents in paints altogether: materials are being reformulated to use high solids or hydrophilic technologies. Thermoplastic powder coatings can be applied by flame spraying techniques to produce a suitable surface film. The method is not suitable for ammunition, thin metals or composites, due to the high working temperature. Electrocoating techniques also eliminate the need for VOC solvents by the use of electrodeposition to place the coating on the substrate. The properties of the electrocoated substrates are under investigation.

285. A variety of coating removal technologies are emerging as alternatives to conventional chemical methods. These technologies can be generally characterized as blasting, preferred chemical or direct energy processes. The blasting processes use a high velocity stream of plastic beads, wheat starch granules, walnut hulls, ice, dry ice, water or bicarbonate of soda slurry to remove the coating. Directed energy processes use lasers or high intensity lamps to pyrolize the coating.

286. No one technology is likely to meet all coating removal requirements. In some instances, a hybrid or multi-process approach may be required. The alternate technologies can vary substantially in terms of facility, equipment, operation, performance and compatibility with substrate material. Each of the coating removal technologies offers a more environmentally benign process. However, the waste stream will still require careful management.

6.5.1.1 Aerospace Coatings

287. In response to air pollution legislation, environmentally compliant aerospace coatings are in development. The new materials appear to match the properties of existing materials, but may have a reduced pot life, and a greater sensitivity to surface preparation. Studies are investigating the possibility of providing aircraft with a permanent corrosion protective primer that will last throughout its lifetime.

6.5.1.2 Navy Coatings

288. In order to prevent pollution in the use of TBT paints in dockyards, the UK has developed a system that seeks to minimize the releases of TBT during the refit.

The method has now been approved for use, and represents the so-called Best Available Technology for the ship refitting industry. Alternative materials are being developed to work using the same principle. These are generally less effective, but are still toxic to the organisms. Work in the United States, UK, Canada, Germany and the Netherlands is trying to tackle this problem.

289. Another approach is to produce so-called low free energy materials, which make it more difficult for the mollusks to attach to the ship's hull. This work is underway in the United States, and trial patches of materials have been applied to a number of working ships. Hydrodynamic Laboratory Trials are also taking place to evaluate the coatings. Toxicity tests of the silicone-based materials are in progress.

290. A number of countries are investigating the use of naturally occurring antifoulants. A joint UK-Netherlands study for the EU has examined the ability of Caribbean sponges to repel barnacles, and hopes to isolate those active ingredients that are not toxic. In Australia, proteins have been isolated from bacteria and algae that have antifoulant properties. French biodegradable biocides are also proving to be of great interest.

291. An antifouling coating database has been set up using the Microsoft Access PC system, and this information should be made available on the Internet. Antifouling was the subject of a former NATO CCMS study program with the French as Chair. Formal contacts could be made between this group and LTSS/44.

6.5.1.3 Army Coatings

292. Most NATO countries have introduced high efficiency transfer equipment. A new low-VOC CARC material is required.

6.5.2 Inorganic Coating Technologies

293. Surface coatings are widely used in product design where specific surface characteristics are required or desired that cannot be provided by the parent or base metal. It may be more cost effective to add surface coatings to relatively inexpensive base materials rather than to fabricate or cast entire parts or assemblies from the higher cost materials that serve only a limited role in the design. In other situations, it is desirable to fabricate a part from a resilient material to absorb rapidly applied loads, and then to surface harden it for wear characteristics. The final design is both resilient and tough, a combination not easily found in one homogeneous metal.

294. Another aspect of this problem is noted when cold working non-ferrous alloys, which progressively harden as compaction and deformation occurs. For most cold

worked metals this hardness resulting from deformation is stable at ambient temperatures. Lead, zinc and tin, however, will recrystallize at room temperatures over time and lose the effects of mechanical hardening. The copper-zinc, copper-zinc-tin alloys (and numerous variations that may include manganese, aluminum, nickel, lead, beryllium and zirconium in the alloy — brasses, bronzes and cupronickels) are generally stable after cold working but often require plating for surface hardness, corrosion protection or appearance.

295. Ideal design selection of base materials for fabrication and assembly occasionally place two dissimilar metals into direct contact. Negative consequences may arise in the form of galling, binding or untimely wear between the parts. Chromium- or nickel-plating technologies are often employed to minimize or eliminate this situation. Further problems may arise in the proximate use of dissimilar metals where the environment may give rise to galvanic activity resulting in the untimely wearout of parts. Similar electrolytic effects are noted when dissimilar metals are coupled in the presence of sea water, which may lead to premature corrosion and failure. Chromium, nickel, zinc and certain heat treatments (i.e., Parkerizing) may be employed as surface coatings to minimize these difficulties. In other cases, surface coatings may be used to provide heat resistance or insulation for metallic components that would otherwise fail in the presence of elevated temperatures. Silicones, zirconia, alumina and other ceramic coatings may be employed for heat protection purposes.

296. Another application area for successful use of inorganic surface coatings is when they are added to protect a substrate. By dissolving, wearing away or ablating, a surface coating offers protection to the parent or base material during its life span. Examples include galvanizing of steel (zinc coating), chrome plating of steel and brass in the marine environment and ceramic coating of rocket nozzles.

6.6 ALTERNATIVES AND POSSIBLE SOLUTIONS

297. The ultimate goals for NATO Pollution Prevention programs on organic and inorganic coatings are the development of non-toxic environmentally compliant coating systems, and the elimination of the need for expensive control equipment.

298. Some progress has been made in the replacement of tin-based antifouling coatings by low free energy materials, which appear to be inert to marine organisms. Much work remains to be done on the application process for the materials. Work on naturally occurring antifoulants appears many years from fruition. Powder coating technology has the potential to eliminate the need for the use of VOC solvents, but may be difficult to apply to larger items. However, progress has been slow in most other areas.

299. The following research and development programs for organic contaminants have been identified as being of high priority for NATO by the LTSS/44 experts:

A. Environmentally compliant coatings with longer lifetimes than existing VOC based coatings;

B. High efficiency spray equipment;

C. Non-toxic antifouling coatings;

D. Non-chromated corrosion inhibiting coatings for aircraft;

E. Primerless coatings for aerospace and naval aircraft;

F. Non-chromated conversion coatings;

G. Zero-VOC coating systems;

H. Low-VOC coatings applicable in colder temperatures;

I. Low-VOC, chemical agent resistant, corrosion protection, camouflage coating; and

J. Cost-effective non-chemical methods for coatings removal.

300. For inorganic contaminants, the following research and development areas have been identified as significant to NATO:

A. Plating processes must be modified in order to:

(1) minimize or eliminate heavy metal/hazmat generation;

(2) develop a scrub process to reduce toxicity (in the spirit of pollution prevention); and

(3) develop alternatives to plating processes for inorganic coatings not applied by electrolytic methods and for organic coatings of low toxicity.

B. Heavy Metal Elimination/Minimization

(1) alternatives to chromium, cadmium, copper, lead; and

(2) materials substitution (i.e., zinc moly coating vs. zinc chromate).

C. Heavy Metal Waste Stream Minimization

(1) process discharge reductions related to surface preparation;

(2) "clean" abrasive blast media (i.e., specified heavy metal/contamination levels for blast media); and

(3) reduction and/or redirection of plating effluents.

6.7 CONCLUSIONS

301. The LTSS/44 study experts sought alternative processes that would minimize or eliminate the offending organic and inorganic compounds, substitute benign substances for contaminating substances, or develop management and logistics approaches to speed the gross reduction of released compounds.

302. The following surface preparation and coating processes should form the focus for future Research and Development:

A. Painting;

B. Hot Dipping;

C. Metal Spraying;

D. Electroplating;

E. Vapor Deposition;

F. Metallizing;

G. Plasma Flame Spraying;

H. Non-organic degreasing; and

I. Surface cleaning methods.

303. NATO nations have responded well to environmental legislation by using Pollution Prevention approaches to coatings. NATO needs to continue its development of environmentally compliant coating systems for military operations and uses. New technologies have to be developed to achieve the long term goals of environmentally sound

coating systems that outperform existing systems. Work on surface preparation and coating removal technologies that eliminate the need for VOCs and minimize the use of toxic heavy metals must be encouraged and supported. The highest possible technology transfer efficiencies will be required for new application techniques.

6.8 RECOMMENDATIONS

304. The following specific recommendations are made:

A. Organic Coatings

(1) Research on low free energy coatings as an alternative to TBT anti-fouling coatings should be accelerated.

(2) Antifouling systems based on naturally occurring materials should be pursued for a long-term solution.

(3) Powder coating technology should be developed for larger substrates.

(4) Environmentally compliant coatings should be developed with properties superior to the existing materials.

(5) Non-chromated corrosion inhibiting and conversion coatings should be developed.

(6) Cost-effective non-chemical coatings removal methods should be developed.

(7) Development of low VOC coatings should be accelerated.

(8) Primerless aerospace coatings should be researched and developed as soon as practical.

(9) High efficiency coatings transfer equipment should be developed.

B. Inorganic Coatings

(1) Chromium in electroplating and conversion coatings should be eliminated.

(2) An environmentally safe conversion coating process for magnesium should be found.

(3) Waste streams from metal stripping processes should be controlled.

(4) Rinse water from plating should be recycled to recover heavy metals for safe disposal.

(5) Safe alternatives to electroplating and spray deposition of metals should be developed.

(6) Acceptable substitutes for cadmium should be developed.

(7) Physical Vapor Deposition should be perfected as a substitute for plating processes.

(8) The use of zinc-nickel and tin-nickel instead of cadmium for electroplating should be evaluated.

(9) Non-chromate based conversion coatings and sealers should be developed for use during anodizing.

(10) Non-chromate, non-carcinogenic (low toxicity) etching methods for structures should be developed, with particular attention to bonding titanium with polymeric substances.

(11) Non-chromate based conversion coatings and sealers should be developed for ship repair.

(12) Non-chemical methods for surface preparation should be developed.

305. Specific project descriptions for all of the above may be found in Appendices P and Q to this report, in the document entitled Technical Data and Information: Appendices to LTSS/44 Report.

CHAPTER 7

SHIPBOARD SOLID AND LIQUID WASTE

7.1 DESCRIPTION OF THE PROBLEM

306. The shipboard waste stream is a source of pollution in the world's bodies of water. The topic of pollution is a very sensitive one, especially for nations who depend upon the oceans' waters for their commerce, for tourism, for food, and for important raw materials. While the NATO navies constitute a very small fraction of the total population of ocean-going vessels, NATO is increasingly determined to reduce the environmental impact of its naval operations. The disposal of liquid and solid[21] waste at sea may affect the environment in a number of ways. Marine mammals and birds can ingest or become entangled in non-biodegradable solid waste. Waste can damage micro-organisms in the sea and interfere with natural food chains. Solid and liquid waste can wash up on shores, affecting coastlines. Waste streams can affect fishing areas and sensitive marine environments (such as coral reefs).

307. Recognizing the potential threats to the environment caused by both solid and liquid wastes, international agreements on the reduction or elimination of shipboard waste streams have been implemented. The International Convention on the Prevention of Pollution from Ships (MARPOL), approved in 1973 and amended in 1978 by the International Maritime Organization (IMO), imposed significant restrictions on solid waste disposal by ships at sea in its Annex V; in turn, MARPOL's Annex I and its pending Annex IV impose significant restrictions on liquid waste disposal. Furthermore, MARPOL specifies general restrictions applicable throughout the world's oceans and seas (beyond territorial waters), as well as more rigid restrictions pertaining to special areas. However, it should be noted that at the present time, military vessels are exempted from complying with MARPOL provisions, although they are expected (and encouraged) to comply to the maximum extent possible.

308. One of the major challenges facing the NATO navies today is to identify ways in which existing ships—as well as ships now being built, which will operate for 40–50 years—can comply with international and national environmental regulations. The possible solutions to these problems vary across the nations, depending in large part on their operational requirements (e.g., how long ships are deployed, the size of their crews, the types of missions they are called on to fulfill, etc.). For example, blue-water navies, which

---

21 Shipboard solid waste is composed of paper and cardboard, metal and glass, plastics, wood and dunnage, textiles, and food. This study expressly has not addressed hazardous solid wastes.

must operate at sea for extended periods of time, obviously face different problems from green-water navies, whose duration at sea is less than 10 days. Similarly, a military combat logistics force (CLF) ship, which is manned by a relatively small crew, does not have nearly as large waste streams as warships, which have high crew densities.

309. In many cases, pollution prevention technology is not yet able to address fully all the shipboard waste stream problems. Additionally, from the perspective of today's warship designers, environmental systems have not been a top priority and have not been adequately incorporated into the design and acquisition process; rather, the designer focuses above all on the ship's military missions and its combat systems. Yet in order to meet the military mission, it is increasingly important for navies to obtain new environmentally compliant technologies in order to ensure the operational freedom necessary to operate anywhere at anytime.

310. One important factor to recognize is that environmental legislators, which drive the need to create environmentally compliant technologies, may not fully appreciate the space constraints involved due to high densities of equipment and crews. As noted earlier, military ships simply do not have the excess space to accommodate bulky environmental equipment or storage areas for holding waste. Laws and regulations may not recognize the full difficulties of employing current technological capabilities to address the waste streams.

7.1.1 Shipboard Solid Waste

311. The major requirements of MARPOL Annex V pertaining to all sea areas are:

A. A total ban on the discharge of plastics anywhere at sea;

B. Dunnage, lining and packing materials that float cannot be discharged when less than 25 nautical miles from land; and

C. Food waste and all other garbage (including paper products, rags, glass, metal) cannot be discharged when less than 12 nautical miles from land. (If, however, it has been processed through a comminuter or grinder to a specified level, it can be discharged not less than 3 nautical miles from land.)

312. The restrictions on disposing of solid waste in "special areas" are even tighter.

313. As defined in MARPOL 73/78 Annex V, a special area means "a sea area where for recognized technical reasons in relation to its oceanographic and ecological condition and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by garbage is required."[22] Special areas are identified in this Annex as: the Mediterranean Sea area, the Baltic Sea area, the Red Sea area, the "Gulfs area," the North Sea area, the Antarctic area, and the Wider Caribbean Region.[23] As of today, the North Sea, Baltic Sea and Antarctic special areas are in effect. The major requirements in special areas are:

A. A prohibition on discharging any plastics or other garbage (including paper products, rags, glass, metal, dunnage, lining and packing materials) when operating in a special area;

B. A prohibition on discharging food waste when less than 12 nautical miles from land.[24]

314. Until recently, military ships conducting underway operations were not precluded by international protocols or pressures from dumping their solid waste over the side when out of sight of land. MARPOL 73/78 provides an exemption from the Annex V discharge restrictions for public vessels (e.g., military ships), but it expects that these ships will comply to the full extent that is practicable. As a result of legislation by national governing bodies and pressure from environmental protection groups, warships are finding that the MARPOL 73/78 exemption is no longer available or prudent to use. As an example, in 1987 the US Congress enacted the MARPOL Annex V requirements in the Marine Plastic Pollution Research and Control Act (MPPRCA). While the Congress granted several years' grace before Navy ships must comply, it is apparent that the international trend is for increased restrictions to be placed on discharging shipboard-generated waste in territorial seas and international waters.

315. Most shipboard solid waste is directly attributable to the people embarked in ships. Naval vessels have a much higher population density than commercial vessels, except for cruise ships. The amount of solid waste generated aboard ship depends upon the crew size, the ship's mission duration, different packaging approaches among countries, etc. To illustrate such differences, Table 7.1 indicates the volume of various types of waste

---

22 Regulation 1, Annex V of MARPOL 73/78, p. 441.

23 See Regulation 5 in Annex V of MARPOL 73/78 (p. 443) for the detailed MARPOL geographic definitions of these special areas.

24 In the Wider Caribbean Region, if food wastes have been passed through a comminuter or grinder to meet the specified level, they can be discharged not less than 3 nautical miles from land.

materials on an average German Navy ship and a US Navy ship. It is important to recognize that warships have not been constructed with any dedicated storage capacity for solid waste generated on board ship. The first example in which this storage issue is consciously being addressed is the new German frigate 124 class, where a 50-square-meter cooled space has specifically been included in the ship's design for solid waste storage. The Royal Netherlands Navy policy is now to include treatment/process and storage space in the design of new ships.

Table 7.1. Comparison of Shipboard Solid Waste Generation, By Volume

Type of Waste	Percentage of Volume	
	Germany	United States
Metals/Cans/Glass	30	11
Paper/Cardboard	16	44
Plastics	14	38
Food	12	7
Other (cannot be identified)	28	—

316. Table 7.2 shows the weight and volume of solid waste generated by a variety of US Navy ships. While in peacetime, warships usually do not remain continuously at sea for the full mission duration shown, during a contingency they could be required to do so in any one of the several MARPOL Special Areas where they now operate, such as the Mediterranean or the Persian Gulf. Virtually all NATO navies conduct operations in one or more of the special areas, and include ships similar to some of those included in Table 7.2.

Table 7.2. Daily Rate of Solid Waste Generation*

			Paper/Cardboard		Plastics		Metal/Glass		Food	
Ship	Crew Size	Mission Duration (Days)	Cu. Meters	Kgs	Cu. Meters	Kgs	Cu. Meters	Kgs	Cu. Meters	Kgs
CVN	7500	60	33	3171	27	566	8.4	1540	4.8	3443
LSD 41	850	30	4.5	430	3.6	77	1.1	208	0.78	467
DD 963	400	30	2.0	199	1.7	36	0.6	97	0.3	217
FFG 7	225	30	1.1	111	1.0	20	0.3	54	0.1	120
MCM 1	85	5	0.4	43	0.4	9	0.1	20	0.06	45

* Numbers may vary with mission profile.

317. The MARPOL 73/78 Special Area waste disposal restrictions will become operative in each area when sufficient bordering states certify to the IMO that adequate waste reception facilities are available to handle the solid waste generated by ships in that special area. Additional maritime areas could be declared pollution-free areas in the future by the IMO or by regional consortia of the littoral nation-states. Environmental protection organizations will continue to draw attention to maritime pollution. Already ship commanders and masters are taking actions to minimize their ships' waste streams in areas where no pollution prevention restrictions are operative, because they want to reduce the danger of their solid waste washing ashore, which results in negative public reaction and even the threat of legal action.

7.1.2 Shipboard Liquid Waste

318. Shipboard liquid waste consists of two categories: oily waste and non-oily waste. The NATO and MARPOL definitions of oily wastes are as follows:[25]

A. Bilge water: Water generated in the bilge of ship's machinery spaces that may be contaminated with oil and other substances, some of which may be harmful.

B. Ballast water: Water taken on board a ship to improve ship's stability.

---

[25] NATO definitions of these terms are included in The Allied Maritime Environmental Protection Publication 7 (AMEPP 7), "Glossary of Terms and Definitions Used in the AMEPP Series."

C. Separated oil: Oil that has been separated from the oily mixture.

D. Waste oil: Contaminated oil or oil whose characteristics have changed markedly since being refined and is not suitable for its original use.

319. The NATO definitions of non-oily wastes are as follows:

A. Blackwater (sewage): Includes: drainage and other wastes from any form of toilets, urinals and water closet (WC) scuppers; drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located on such premises; and other waste waters when mixed with the drainage defined above.

B. Graywater: Drains from culinary activities, bathing and laundry facilities, and deck drains or other non-oily waste water drains (excluding sewage).

320. The number of serious oil spills from commercial vessels and the considerable amount of non-oily liquids discharged by ships at sea and in coastal waters, have focused much attention on preventing future pollution, especially in territorial waters and special areas. Because of the potentially harmful effects of liquid wastes on marine life and on coastlines, various international, national and state protocols have imposed restrictions on ships' discharging these waste products into the water. In the case of liquid waste, MARPOL Annex I stipulates the following:[26]

> In general, oil-contaminated water and oily wastes (e.g., from engine room bilges, ballast water, tank strippings, and used lubricating oil) in excess of 15 ppm must be retained on board ship while at sea, to be discharged to a certified port reception facility.

321. According to Annex IV, which has been drafted and is pending approval by the IMO's member nations, ships will either need to have an approved sewage treatment plant to meet MARPOL specifications or will be required to operate under the following restrictions:

A. Blackwater cannot be discharged within 4 nautical miles of shore;

B. Blackwater can be discharged more than 4 nautical miles from shore if it has been comminuted and disinfected with an approved system;

---

26 Refer to Regulation 9 of MARPOL Annex I for more detailed information.

C. Blackwater can be discharged more than 12 nautical miles from shore if certain holding, discharge and speed requirements are met.

322. Graywater discharge is not currently restricted by MARPOL, but it is defined in Annex V. Therefore, in considering pollution prevention technologies, it is important to identify possible solutions to graywater contamination. Moreover, NATO nations have already determined that optimum treatment technology development is more likely to be successful if waste oil, oily water, blackwater and graywater are collected separately. Combination of these waste streams, if warranted, should only occur in the treatment system under controlled conditions.

7.2 IMPLICATIONS FOR THE MILITARY MISSION

323. The impact of MARPOL 73/78 and future marine pollution prevention protocols, *particularly if public vessels are denied exemption from their provisions*, is that warships unable to comply with the restrictions will effectively be prohibited from operating in those maritime areas. This would have serious implications for national security. Not surprisingly, among the NATO nations there is a growing interest in environmental compliance for military, logistics and public relations reasons.

324. From a strictly military perspective, the creation of environmentally sound ships will allow NATO navies to operate worldwide, with no inappropriate dependence on shore support and no unreasonable costs imposed by regulations. NATO believes that a "green ship" can reduce its logistical requirements because the ship would be able to use more ports than current ships are able to do. Namely, the green ship will be able to deliver waste to installations ashore, using standard connections, in accordance with STANAG 4167 and MARPOL. Moreover, the more waste a green ship can reduce or destroy on board, the less waste will need to be transported to shore, which reduces handling and reception costs and expands the number of ports the ship can use. Finally, the public image of NATO navies will be enhanced as they attain higher levels of environmental compliance and pollution prevention activities. It is important to remember that while international bodies like the IMO may have difficulty in dealing effectively with violators, national governments can be expected to prosecute offenders to the full extent of the law.

325. The extent to which existing and emerging environmental regulations will affect NATO's military mission is dependent on a number of important factors. First, what is the type of mission? Is the navy (or an individual ship) to execute primarily blue-water operations or coastal operations? Does its mission require that the ship remain on station, or is it free to go out to sea, where it would be allowed to discharge some of its wastes freely? The answers to such mission questions will shape the way in which environmental requirements are met.

326. Second, what is the duration of the mission and what is the size of the crew? In cases where the mission lasts less than 10 days and there is a small crew, the likely solutions will be storage and retrograde with some form of volume reduction (where permitted by national regulations). The waste can then be off-loaded when the ship returns to port, or it could be off-loaded to a supply ship. When the mission lasts well in excess of 10 days and there is a large crew, the ability to store and retrograde wastes is extremely difficult, if not impossible. New and very costly technology will be needed to comply with environmental regulations.

327. In short, warships have a very limited capacity to store waste material. Ships that comply with prohibitions against dumping of solid waste by retaining unprocessed solid waste on board while they are underway risk degraded ship safety and jeopardy to the health of the crew. For example, solid waste can constitute a fire hazard, and any leakage on deck can cause safety problems. Overall sanitation and quality of life considerations are, of course, other important factors in the storage equation.

328. Third, where is the mission being carried out? As already alluded to, MARPOL has identified a number of Special Areas, where restrictions on discharges are even more strict (and are sometimes entirely prohibited). Similarly, some countries (or a country's regions/states/provinces) have implemented more rigid discharge guidelines than those that prevail elsewhere. Thus, the ship's location will determine how "green" its operations must be,

329. Fourth, the goal of the NATO navies must be to have access to ports, civilian or military, developed or undeveloped. The ship-to-shore interface will determine whether the vessel is capable of using any given type of port and its facilities.

7.3 ALTERNATIVES AND POSSIBLE SOLUTIONS

330. The preferred alternative—to eliminate solid and liquid wastes at their source—is not an option aboard manned vessels. There are effectively three ways to address pollution prevention on board ship: first and foremost, minimize the amount of pollution created (by reducing the volume of water used, employing vacuum technology, etc.); reduce the amount of pollution at the source (by using less of the pollutant itself or by substituting benign or biodegradable materials wherever possible); and third, develop more effective processing methods for the pollution that is created. A number of NATO nations are pursuing these alternatives, and some results are quite promising.

331. The alternative(s) selected must meet specific Navy requirements concerning the ship size, crew size, mission duration and operational requirements. Thus, it should be noted that, in contrast to some of the other areas examined by LTSS/44—such as

petroleum, oils and lubricants—the applicability of civilian technology to naval vessels can be limited for several reasons, including: greater space constraints on naval vessels, the need for them to be at sea longer between port calls than civilian vessels, the requirement that the ship's infrared signature not be altered and that the pollution control device not create any electromagnetic interference (EMI), and the need to continue to meet military specifications, although some of these specifications are being reduced (e.g., a naval vessel still must be more "ruggedized" than a civilian one in order to withstand greater shocks).

332. Differing regulations on the processing and disposal of shipboard waste, as well as differing duration of time spent at sea among nations, are clearly other important considerations when examining the range of environmental technology options from which a navy can choose. For example, many European navies spend no more than 10 days at sea at a time, while the US Navy must spend considerably longer at sea between port calls and a given ship is routinely away from home port for 6 months every 2 years. For those with shorter deployment schedules, simple volume reduction and storage of the waste on board may be an appropriate and adequate solution; this is the approach that Spain, for one, is adopting. Outlined in Appendix R (in the document entitled Technical Data and Information: Appendices to LTSS/44 Report) are a sampling of the national regulations on shipboard waste for the various NATO Navies, as prepared by NATO's Special Working Group (SWG)/12.

333. Another issue to consider is compliance with international protocols, such as MARPOL, which is a national decision. Compliance by navy ships with these restrictions should be viewed in two discrete categories: (1) existing ships and (2) newly designed ships for the future. What should also be taken into account is the level of compliance: full and absolute compliance (which can and should be expected for future ships) and compliance meeting the spirit of the regulation (which may be necessary for some existing ships operating under certain conditions). Existing navy ships are greatly constrained in space, weight and manpower. Retrofit of waste processing systems is very expensive (typically, the cost is 2–10 times the equipment acquisition cost). In light of already constrained defence budgets, which are not likely to improve in the foreseeable future, existing ships should choose waste processing solutions that meet MARPOL requirements "as far as reasonable and practical": systems should be chosen that provide the most environmental benefit at the most acceptable cost.[27]

---

[27] For example, the discharge of pulped paper and cardboard in Special Areas may not meet the letter of the regulation, but it should be permitted for current navy ships as the most reasonable and practical solution with minimal environmental impact.

334. In contrast, new ships should integrate into their design new pollution control technology to permit environmentally sound destruction of waste on board. However, these technologies still require significant technology base and development work; moreover, assessments of these technologies must consider the total environmental impact, including energy consumption, emissions and the ship-to-shore interface.

335. In summary, a variety of costs and benefits must be taken into consideration when evaluating the options facing the NATO navies. Dedicating specific space to storage of solid and liquid wastes is expensive, as every square meter on a ship is prime real estate. Equipping ships with various waste processors entails not only the equipment capital costs, but the manpower costs to operate and maintain the systems, the energy to operate the equipment, and consumables in the equipment that will need to be maintained or replaced periodically. Evaluating these costs to comply versus the implications of non-compliance (including the environmental effects) is often a political decision, and one that must be made wisely.

336. The remainder of this chapter focuses on the alternatives currently available today (now in production), those that will be available in the near term (within 5 years, and are now undergoing test and evaluation), and those for the future (they may be available in the next 5–15 years and still require science and technology work). A brief description of the current and near-term options for dealing with each type of shipboard waste is followed by Tables 7.3 and 7.4, which outline these technologies and their advantages and disadvantages. Appendix S provides more detailed descriptions of some of these technologies, while Appendix T presents data collected by LTSS/44 members on other such technologies.

337. Assuming full MARPOL compliance with Annex V on solid waste, small ships with small crews operating at sea for relatively short missions will consider alternatives that rely on outside support: storage and retrograde with some form of volume reduction (where permitted by national regulations), including compactors and shredder compactors; solid waste may be offloaded at sea to tenders or support ships. Assuming only partial compliance with MARPOL Annex V, the most important considerations in selecting any solid waste processing system will be the reduction of manpower and handling of waste in a manner that has the least operational impact. Small ships with small crews and short missions will likely not install any equipment, while large ships with large crews and long mission duration will consider volume reduction technologies that permit direct discharge with minimal handling. Such technologies include solid waste pulpers for inherently degradable materials and shredders for metal and glass. As for near-term technology for solid waste, improved conventional marine incineration technologies appear to be the only alternative that would allow on board waste destruction. However, these

technologies present serious impediments when backfitted on existing ships, and air emission controls remain uncertain.

338. In the event of full compliance with MARPOL Annex IV, decisions will need to be made on the best way to comply: storage or treatment. Small ships with small crews and short missions will have the greatest flexibility in selecting the best approach, while large ships with large crews and long missions must consider treatment technologies. However, the sheer volume of waste water to be processed demands extremely large treatment systems using conventional technology. New technology must be developed to permit space efficient treatment for blackwater and graywater; such technology will be feasible to install only on new design ships.

339. Finally, full compliance with MARPOL Annex I will also demand either storage or treatment solutions. Which approach is adopted will depend on the ship size, its type of propulsion system, mission duration and projected operating areas. Gas turbine and diesel propulsion systems generally produce less bilge water than conventional steam propulsion systems. As with blackwater and graywater compliance, large ships with long mission durations must consider treatment technologies. Conventional oily water separators suffer from an inability to deal with emulsions. The new membrane ultrafiltration systems in development show great promise for treatment to effluent quality well below the required 15 ppm free oil. Reliable oil content monitor technology should be developed to permit fail-safe operation with real-time effluent quality monitoring. Development of these new technologies needs to be continued to permit space-efficient treatment for oily water.

Table 7.3. Technologies and Alternatives Available Today

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Solid (All Forms)	Storage and Retrograde	•Full compliance with MARPOL •Low equipment acquisition cost	•Packaging cost for the solid waste •No volume reduction •Labor cost •Impact on mission duration •Offload at sea to CLF ship or tender •Requires safe, sanitary, suitable storage site (such as chilled storeroom on Germany's FF 124) •Backfitting very costly •Must segregate food waste from other waste

Table 7.3. Technologies and Alternatives Available Today (continued)

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Solid (All Forms)	Compaction	•Full compliance with MARPOL •Low acquisition cost •Reduced volume reduces disposal costs, in some nations	•Storage of compacted waste required •Processed waste may not meet some national laws or may increase disposal cost •Precludes recycling or makes it more difficult •Cannot process very wet waste
Solid (All Forms, Processed Separately)	Marine Shredder and Compactor	•Full compliance with MARPOL •Low acquisition cost	•Storage of compacted waste required •Offload cost •Containers required (consumables cost) •Processed waste may not meet some national laws or may increase disposal cost •Precludes recycling or makes it more difficult •Cannot process very wet waste

Table 7.3. Technologies and Alternatives Available Today (continued)

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Solid: Metal and Glass	Metal and Glass Shredder	• Low acquisition cost • Volume reduction • Low space and weight requirements • High capacity	• Not full MARPOL compliance unless waste stored • Storage (space and weight) requirements • Offload requirements
Solid: Paper and Cardboard	Inherently Degradable Waste Pulper	• Low acquisition cost • High capacity • Low manpower • Can be used during flight operations	• Not full compliance for paper/cardboard in MARPOL special areas • Installation costs for piping, etc.
Solid: Paper and Cardboard	Commercial Incinerators	• Available • Full compliance with MARPOL	• Cost • Air emissions • Ash disposal • Space and weight requirements • Thermal signature • Public perception

Table 7.3. Technologies and Alternatives Available Today (continued)

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Solid: Plastics	Plastic Waste Processor	• Full compliance with MARPOL • Available • Relatively inexpensive • Low space and weight requirements • Recycle processed waste	• Storage requirement • Offload requirement
Liquid: Oily	Holding Tanks	• Full compliance with MARPOL Annex I	• Limits mission duration
Liquid: Oily	Oil Content Monitor	• Will prevent oil discharge if OWS fails • Shows OWS is working	• Unreliable • Not accurate in turbid or high particulates • Susceptible to "window" fouling • Difficult to keep calibrated

Table 7.3. Technologies and Alternatives Available Today (continued)

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Liquid: Oily	Oil Water Separator-Filter/Coalescer	•Available	•Low reliability •High maintenance •Consumable costs
Liquid: Oily	Oil Water Separator-Membrane Ultrafiltration	•Full compliance with MARPOL •Can achieve <5ppm Free Oil and Grease (FOG) •Can break emulsion	•Membrane life •Membrane fouling •Chemical cleaning •Energy demand •Volume •Cost
Liquid: Oily	Oil Water Separator-Parallel Plates	•Low cost •No moving parts	•No emulsion capability
Liquid: Blackwater	Gravity/Vacuum Collection, Holding, and Transfer (VCHT) Tanks	•Complies with MARPOL Annex IV	•Limited holding tank capacity •Maintenance intensive •Problems with hydrogen sulfide (reduced with VCHT)

Table 7.3. Technologies and Alternatives Available Today (continued)

WASTE	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Liquid: Blackwater	Blackwater Physical/ Chemical Treatment	•Simple •Low cost	•Does not comply with MARPOL Annex IV •Adds chlorine or sodium hypochlorite
Liquid: Blackwater	Biological Treatment	•Complies with MARPOL Annex IV •Relatively low life-cycle cost	•Size •Reliability •Does not respond well to liquid load fluctuation •Needs trained operators •Must not add chemicals that kill biomass •Best suited to small crew size

Table 7.4. Technologies and Alternatives Available In the Near Term

WASTE STREAM	TYPE OF TECHNOLOGY/ PROCESS	ADVANTAGES	DISADVANTAGES
Solid (All Forms)	Advanced Incinerators	•Full compliance with MARPOL	•Exhaust gas treatment •Ash disposal •Big space and weight requirements •Throughput •Feed system •Thermal signature
Liquid: Oily	Developmental Membrane Ultrafiltration Oil-Water Separator	•Produces <5ppm FOG •Breaks emulsion •Long membrane life •Reduced chemical cleaning required	•Not available yet •Will not remove dissolved oil fraction
Liquid: Blackwater	Developmental Membrane/Bio-reactor	•Full compliance with MARPOL	•Size requirement •Must not add chemicals that kill biomass •Needs trained operators

7.4 AREAS FOR FUTURE RESEARCH

7.4.1 Solid Waste Technologies

340. Mixed solid waste except for plastics can efficiently be destroyed by thermal means (burning, plasma arc pyrolysis, etc.). As long as waste is segregated, the

most energy efficient means should be considered for each category of waste. Thermal destruction does not make sense for separately collected metal and glass (unless they are heavily food contaminated); other volume reduction technologies for these forms of solid waste should be pursued.

7.4.1.1 Paper and Cardboard

341. Thermal destruction is the best approach. There are two thermal destruction technologies that are being developed: advanced incineration and plasma arc pyrolysis. These are described in some detail in Appendices S and T.

342. Advanced incineration has the potential of providing better, smaller, cheaper, lighter (sometimes known as "BSCL" for short) and faster combustion of shipboard waste. Specifically, it suggests a number of advantages over any present or near-term system:

A. Full compliance with the provisions of MARPOL as it pertains to solid waste.

B. The emissions profile is improved over present incinerators, because there is a more complete combustion when using higher temperatures and after burners. The combustion result is no fly ash.

C. Reduced space and weight, by using lightweight refractory and less refractory than is used in current incinerators.

D. Reduced manpower requirements by incorporating automation, an improved feed system, fewer problems in handling the residual ash, low maintenance and higher reliability because of its high efficiency.

E. Real-time monitoring of the incineration process.

F. Improved heat exchange (e.g., internal reuse and recycle).

343. The plasma arc pyrolysis technology will provide many of the advantages cited above for advanced incineration. It produces the lowest air emissions with a non-toxic slag by-product, has a high processing rate, and produces the greatest volume reduction compared to any other technology. Nevertheless, at the current state of development, this technology suffers from a number of disadvantages that preclude its use aboard ship. For example, the total installation would be far too large, heavy and noisy for installation in a warship, it would place an unacceptable power demand on the ship's generators, it would increase the ship's infrared signature appreciably, and it would create EMI problems with

shipboard systems. Finally, it is much too costly for outfitting in navy ships. Further science and technology work needs to be conducted to optimize reaction kinetics, develop light-weight ceramics and generally address the problems it currently poses for use on warships.

344. Molten salt and molten metal technologies are too immature to be developed for shipboard use during the next 15 years.

7.4.1.2 Metal and Glass

345. Compaction and shredding are the only technologies that are expected to deal with these forms of shipboard solid waste within the time frame of this study. Principal issues associated with metal and glass are:

A. Material handling, specifically automated handling and storage.

B. Solutions to food-contaminated metal and glass. If they cannot be dealt with in a cost effective manner, thermal destruction may be the only viable solution. Options include advanced incineration and plasma arc.

7.4.2 Food Waste

346. While food waste aboard ship is not presently a problem with respect to environmental compliance (e.g., restrictions imposed by MARPOL or other international protocols), it is prudent to consider its disposal in the way ahead. Volume reduction and stabilization technologies such as freeze drying the food waste, with automated energy-efficient technology that emphasizes the "BCSL" approach for shipboard use, is a promising path that research should pursue with respect to this form of shipboard waste. However, other technologies being researched to deal with other forms of shipboard waste may have future applicability to food waste:

A. Supercritical water oxidation (SCWO). This technology is being developed to deal with organic waste, specifically with graywater and blackwater (see Appendix T). The waste it will thermally treat must be extensively pre-processed for particle size reduction. In its current state of early development it is far too costly, large and heavy to be adaptable for shipboard use. It must solve a number of design challenges (such as reactor chamber kinetics, reactor chamber materials and feed system design) before it could be suitable for use in a shipboard environment.

B. The development of digesters to treat and dispose of waste is in its infancy, and suffers from the many of the same shortcomings exhibited by SCWO in terms of cost, size and weight, and capacity.

C. Other options for dealing with food waste include thermal reduction technologies and the use of microwaves (but these might pose an energy consumption problem of prohibitive dimensions).

347. All these technologies are expected to remain immature through the next 15 years, hence they are not expected to be developed sufficiently to be applied to the containment and control of food waste. The vast assimilative capacity of the world's oceans to absorb this organic (hence bio-degradable) form of waste should continue to be the first choice for dealing with food waste. Food waste should be pulped before discharge overboard to enhance its assimilation, but this technology is available today and is employed by most navies.

7.4.3 LIQUID WASTE

7.4.3.1 Oily Waste

348. This category includes both oily waste bilge water and waste oil. The focus of future research should be on separating and concentrating the oil within the bilge water to form sludge, which can then be stored or dealt with by thermal destruction. Means of coping with heavy metals in the oily waste concentrate need to be found.

349. Disposing of waste oil through thermal destruction may become an option. However, research should be directed toward developing improved technology for shipboard reprocessing of waste oil, so that it can be recycled and reused in such processes as incineration.

350. Current technology in ships does not permit the segregation of various waste oils and oily waste water; they are pumped into waste oil stripping tanks. Future research and technology should be focused both on source reduction—reducing the amount of oil that is expended and discarded from machinery—and on segregating oily waste and waste oil, so that the different oils can be dealt with discreetly.

7.4.3.2 Ballast Water

351. There are two forms of ballast water: fuel compensated ballast and clean ballast. They pose different problems in terms of their potential impact on the environment.

352. Fuel compensated ballast tanks are found in some cruisers, destroyers and other combatant ships, and in diesel submarines. The ballast water taken into fuel tanks becomes contaminated with fuel oil. This becomes a pollutant when pumped overboard. Future work is needed to produce a high capacity separation system, so that the oil can be removed from the ballast water before the ballast water is discharged into the sea. There is also a need for real-time monitoring and control systems that can be applied to all facets of a warship's fueling, operating, and refueling process.

353. Clean ballast tanks are installed in a number of different types of warships, especially amphibious ships and submarines. They are used for stability and to change the ships' draft. The environmental concern is that clean ballast tanks not inadvertently convey non-indigenous species from one part of the world's seas to another. Future research associated with this environmental concern should seek to develop a management and control system that would prevent such occurrences, without needing to employ toxics to destroy non-indigenous species that are taken into clean ballast tanks.

7.4.3.3 Blackwater

354. It is expected that ongoing research and development will produce the bio-reactor and membrane systems in the next 5 years that are required to deal effectively with black water pollution from warships. The remaining challenge for future research will be to apply new technology, such as SCWO, to black water. One approach may be to focus on storing and thermally treating the black water sludge that is produced by the bio-reactor and membrane systems.

7.4.3.4 Graywater

355. As noted previously, no international protocol exists that prohibits or restricts the discharge of graywater in the ocean. However, it is expected that within the next 15 years, the international community will seek to address the pollution that is introduced into the sea by ships' graywater discharges. The best way to deal with graywater pollution is at the source, through water minimization. Low water use technologies must be developed and applied to shipboard scullery equipment, laundries and bathing facilities. Alternatively, technology may be able to produce a means of cleaning certain materials without the use of water (e.g., ultrasonic cleaning). A complementary approach is to attack the pollutants within graywater, by separating and concentrating them for destruction by means of emerging technologies including supercritical water oxidation.

7.4.4 Integrated Waste Treatment

356. Thus far the environmental research and ship design communities have dealt with the problems of shipboard waste pollution more or less on a segregated basis.

That is, containment and destruction of solid waste has been pursued separately from comparable research and technology designed to deal with liquid waste. In the long-term, the ideal would be to manage the shipboard waste stream on an integrated basis, so that all forms of waste could be dealt with using an integrated waste treatment system within the ship. This goal should be an area of future work. It probably can be accomplished by one or more of the incremental efforts that follow.

7.4.4.1 Combined Blackwater and Graywater Treatment System

357. Combined treatment will probably be based on a bio/membrane ultrafiltration system. It would be dependent on achieving vacuum collection of blackwater and minimizing the creation of graywater; the resulting sludge would then be subjected to thermal treatment. These individual technologies will probably become available in the near term, but integrating them and fitting them into warships will certainly not be possible until the long term.

7.4.4.2 Combined Treatment of Oily Waste, Blackwater and Graywater

358. It is believed that the best approach to achieve this combined treatment would be to treat oily waste separate from the other two components of liquid waste, then combine the concentrates from all three components for thermal treatment; supercritical water oxidation is the most likely thermal technology.

7.4.4.3 Mixed Solid Waste Treatment

359. This research and technology effort would merge the two principal forms of solid waste—metal/glass and paper/cardboard—into a common waste treatment system that will use thermal destruction technologies that employ either advanced incineration or plasma arc pyrolysis.

7.4.4.4 Combined Liquid and Solid Waste Treatment System

360. A system capable of dealing with a combined liquid and solid waste stream is not achievable within the timeframe being addressed by this study. It will certainly depend on extracting and concentrating the pollutants as either a sludge or solid form, and then subjecting it to thermal destruction in the combustion system developed for dry waste. The magnitude and cost of such a combined system would make sense for future installation only in the very largest warships that have large crews and operate for prolonged time periods at sea.

7.5 CONCLUSIONS

361. Present shipboard technology offers acceptable environmental protection for the short term. However, the goal of the scientific environmental community and ship designers must be to investigate future technologies that will be able to prevent pollution of the seas to the maximum extent possible without ignoring operational capabilities, space and energy constraints, and economic considerations.

362. The conclusions reached about future pollution prevention efforts on ships are:

A. Technologies selected will vary by country and by ship type, based on the ship size, mission duration, crew size, etc.

B. The selection of the appropriate solution(s) is often a political decision, but this decision must be based on scientific analysis of the full range of costs and benefits for each option.

C. In some cases, the use of commercial grade equivalent equipment is a viable alternative for certain navies or certain types of ships. Specifically, these commercial options are more appropriate for ships whose mission duration and distance from logistics support are not as long as those envisioned for US Navy ships, for example.

D. New design ships will have many more environmental technology options available to them than existing ships. Backfitting existing ships with new technologies is, as a rule, prohibitively expensive and unrealistic.

E. When assessing individual technologies, their compatibility with the ship's overall design is an important consideration.

7.6 RECOMMENDATIONS

363. Based on the analysis contained in this chapter, the following are recommended:

A. Environmental compliance considerations must be incorporated in the early phases of ship design, so that future ships will be able to operate anywhere at anytime.

B. Gaps in shipboard waste treatment technologies should be further identified and prioritized.

C. Selected technologies should be investigated further, preferably through international cooperation. In times of declining defence budgets, it is impossible for any one nation to address all these forms of pollution and potential technological solutions independently. Moreover, in conducting extensive evaluative tests on shore and at sea, international collaboration should be encouraged that involves civilian companies, scientific experts, and Ministry of Defence representatives.

D. Specific important areas for cooperative R&D work on shipboard waste streams include: clean thermal destruction; an oily water separator that consistently meets international discharge standards; an aerated wastewater membrane treatment system; and effluent quality monitors.

E. Future research should focus not only on individual technologies for specific waste streams, but also on the creation of an integrated waste treatment system. This could also be an area for international cooperation.

(This page intentionally left blank)

CHAPTER 8

PESTICIDES

8.1 SCOPE AND NATURE OF THE PROBLEM

364. The armed forces are constantly faced with the problem of protecting military personnel from disease vectors and military property from pest damage. Also, Defence departments require land and facilities for training and accommodation, which are prone to pest problems. Increasingly, national legislation on pesticide usage, particularly bans and restrictions, have the potential to affect military capability. It should be noted that the application of pesticides is, by definition, deliberate pollution.

8.2 IMPLICATIONS FOR THE MILITARY MISSION

8.2.1 STANAG on Chemical Methods of Insect and Rodent Control

365. NATO is already active in the field of pesticides, having drawn up STANAG 2048 on chemical methods of insect and rodent control, AMedP-3. Participating nations agree to keep each other informed of chemical methods of insect and rodent control used within their armed forces. The following information is supplied and regularly updated:

A. Agents used;

B. Aim of application;

C. Mode of application;

D. Effective compounds;

E. Information on necessary precautions;

F. Names and addresses of agent manufacturers;

G. National identification/supply-code number; and

H. National laws and/or regulations restricting the use of agents or methods.

366. The so-called custodian of AMedP-3 is the Federal Republic of Germany, who provides modifications of the above information. The list of ratifying nations includes Belgium, Canada, Denmark, France, Italy, Netherlands, Norway, Turkey, UK and the US.

8.2.2 Methyl Bromide as Ozone Depleting Substance

367. Methyl bromide is used by both the military and civil sectors as a fumigant for controlling a wide spectrum of pests. It is versatile and can be applied using pressurized cylinders. Seventy percent of its use is as a soil fumigant for growing nursery crops, vegetable, fruits, ornamentals and tobacco. The contribution of methyl bromide to the ozone depletion problem will lead to restrictions on its use in developed countries.

8.2.3 Pest Control in the United States

368. Following the publication of a National Academy of Science report on pesticides in children's food in June 1993, the US Department of Agriculture (USDA), the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) announced a joint commitment to reduce the risks to people and the environment associated with pesticides.

369. The US DoD has 470 major installations covering 25 million acres, with 2.5 billion square feet of facilities. This presents a wide range of pest problems that require control. The US DoD is committed to reducing the use of pesticides by 50 percent over the period of 1993 to 2000. This policy is implemented by the Armed Forces Pest Management Board, under the Deputy Under Secretary of Defence (Environmental Security), and will significantly decrease future problems on DoD installations.

8.2.4 Pest Control in Canada

370. The Canadian Department for National Defence has committed itself to reducing the use of pesticides by 50 percent from 1993 to 2000 by logistics management and materials substitution. Federal Government policy now requires that all departments have Integrated Pest Management (IPM) programs, which are required to:

A. Reduce the use of pesticides by improving application methods and the timing of the sprays;

B. Replace pesticides with less toxic or non-toxic alternatives and preventative management;

C. Redesign the underlying management system to prevent pest problems and conserve beneficial species.

371. All bases must now develop IPM plans and arrange to train specialist staff.

8.2.5 UK Pest Control

372. The UK Ministry of Defence (MOD) owns large areas of land that require pest control. A pest control policy has been developed using codes of practice approved by either the UK Health & Safety Executive or the World Health Organization. Approved pesticides are issued via a "pharmacy" system, requiring the authority of local medical and environmental health officers. Storage and transport of pesticides complies with all legislative requirements. All staff using pesticides receive training to meet the requirement of UK legislation.

8.2.6 Pest Control in Germany

373. The regulations on pesticide use in Germany for army training areas are the same as for agricultural and horticultural uses, and are based on the concept of Integrated Plant Protection. The legal definition of integrated plant protection is set out in Regulation P2(1)2 as:

> a combination of methods, the most important being biological, biotechnical, horticultural, and growing and culture techniques that will limit the application of pest-control chemicals to the least amount necessary.

The regulation states that good technical practice must be used, which includes:

A. The use of suitable plants that are least likely to be attacked by disease and/or parasites;

B. Attention to entire regional flora;

C. Diagnosis and assessment, using minimum amounts of pest control chemicals;

D. Precise and appropriate application of pest-control chemicals; and

E. Seeking approval, advice and education from official agricultural services.

8.3 SUMMARY OF THE POLLUTION PREVENTION TECHNOLOGIES AND APPROACHES IDENTIFIED BY THE STUDY NATIONS

8.3.1 UNEP Methyl Bromide Technical Options Committee

374. NATO countries have assisted the UNEP Methyl Bromide Technical Options Committee to propose chemical and non-chemical alternatives to the material. Many of these involve integrated pest management techniques, which are outlined below. A US study has found that pressurized carbon dioxide is a cheaper and more effective solution than methyl bromide for fruit and vegetable preservation. Methyl bromide use is not widespread in the US DoD, or other military organizations.

8.3.2 Pest Management Strategy in the United States

375. The US DoD strategy for pest management and disease vector control is based on eliminating unnecessary pesticide use via IPM, continually introducing safer pesticides, and conducting research on non-chemical and low-toxic control methods. This has been developed in cooperation with the USDA. IPM is a sustainable approach to managing pests and controlling disease vectors by combining biological, cultural, mechanical, physical and chemical tools in a way that minimizes economic, health and environmental risks. IPM uses regular or scheduled monitoring to determine if and when treatments are needed and employs physical, mechanical, cultural, biological and educational tactics to keep pest numbers low enough to prevent unacceptable damage or impacts. Less hazardous pesticides are used as a last resort. Treatments are not made according to a predetermined schedule; they are made only when and where monitoring has indicated that the pest will cause unacceptable economic, medical or aesthetic damage. Treatments are chosen and timed to be most effective and least disruptive to natural controls of pests.

376. IPM in the DoD is based on seven steps that are routine procedures for each pest problem. These steps are:

A. Identification and assessment of pest or disease vector problems;

B. Development of a management plan or strategy that emphasizes natural controls and non-chemical tactics to deal with pest and disease vector problems;

C. Establishment of an action threshold for each pest and disease vector problem to define when corrective action must be implemented;

D. Use of monitoring procedures, such as inspection or trapping for each pest and disease vector;

E. Application of corrective action when a threshold is reached for any pest or disease vector;

F. Use of a documentation system to catalogue monitoring information and to document management problems; and

G. Verification and evaluation procedures to assure the IPM program is meeting stated risk reduction measures and information exists to redesign the IPM plan where required.

8.3.2.1 Integrated Pest Management Plans

377. The US IPM system has been in operation since 1983. The DoD Pesticide Risk/Use Reduction Initiative has set out to reduce pesticide use. Using FY93 as a baseline, a measure of merit of a 50 percent reduction in pesticide use by the end of FY2000 has been agreed. The baseline figure for the US DoD is a total of about 1 million pounds.

378. The range of alternative technologies that have been successful include:

Improved sanitation;

Trapping;

Biological control; and

Drainage ditch clearing.

379. Precision application techniques can be used to target specific pests and habitats, using the least toxic pesticides suitable for the purpose.

380. Key elements of the IPM strategy include training and management systems. Only specially trained personnel are used, the areas are controlled and the amounts of pesticides used are recorded. Good management practices can lead to good containment of the waste streams that encourage pests, thus discouraging infestation. Each DoD unit produces an annual pest management plan outlining how problems will be handled. The plans are reviewed at a higher level, and improvements suggested. The success of the IPM strategy relies upon support at the ground level, but is also supported at the Secretary of Defence level.

381. The results obtained so far show that fewer labor and less pesticides are required. The application is more specific, and poses less health risk to the operator. However, additional manpower is required to carry out surveillance and improve record keeping, at a time of diminishing resources for defence. A cultural change may be necessary to change working practices.

8.3.3 Pest Management Strategy in Canada

382. Some ways of meeting the Canadian Government target on reducing pesticide use are to: track their use; try to forecast the amount needed; and suggest alternatives. This can lead to elimination of waste, and save money. A new reporting system and the associated software is being developed.

383. Staff workshops will be set up before pilot projects begin. IPM training courses started in early 1994 covering general matters and specialist topics such as urban forests and biting fly management. A Pest Management Manual has been produced addressing the following key topics:

A. Pesticide safety and the environment;

B. Management of greenhouse, turf and tree pests;

C. Vegetation management;

D. Management of biting arthropods (mosquitoes);

E. Vertebrate pest management;

F. Structural pest management; and

G. Fumigation and aircraft disinfection.

384. To assist distribution, of the manual it is being translated into French, and a CD ROM may be produced.

385. Canada and the United States have set up a joint pesticide management board.

8.3.3.1 Specific Canadian Pest Control Programs

386. Improved cultural practices, environmental planning, pesticide alternatives, naturalization and communications strategies all have a role in reducing pesticide use. Pest larvae habitats can be identified and larvicides used to eliminate the

problems associated with large area adult pest spraying. Flea beetles have been imported from Europe to control the leafy spurge pest and allow other plants to become more competitive. Studies on grass growth near airfields prone to bird damage have shown that tall prairie grass is less popular with birds than short grasses, and it masks small mammals from predatory birds. Similarly, sonic bird control is being used to keep aircraft hangars free from corrosive droppings.

8.3.4 UK Pest Management Strategy

387. A MOD Pest Control Committee oversees all pest control work in the UK and overseas, and provides policy direction via regular reviews. Pesticides primarily based on organochlorines are now restricted to pentachlorophenol (PCP), and organophosphorus materials have been greatly reduced. Baselines of usage and target reductions are planned for the future.

8.3.5 German Pest Management Strategy

388. In 1991, in the former West Germany, 70 percent of applications were herbicides, 20 percent were fungicides, 6.5 percent were rodenticides, and 3.5 percent were classed as special applications. Forty-nine percent of applications were area treatments, whereas 51 percent were at specific sites. No pest-control chemicals were used on open parts of training areas, except for grass seed raising areas.

389. Herbicides present the major target for reduction and the following approaches are under consideration. The unwanted propagation of plants is to be considered at the planning stage to prevent the need to use pest-control chemicals. Similarly, areas should be designed to enable easy mechanical removal of unwanted plants.

390. The adoption of alternative measures must be accepted by everybody, including the military. It must be realized that alternative procedures may not achieve the 100 percent efficiency of pest-control chemicals. Similarly, the greater costs for personnel, time and materials will have to be accepted.

8.3.6 Moves to Eliminate the Use of Pentachlorophenol (PCP)

391. The UK is actively trying to eliminate the need to treat cotton fabrics with PCP to prevent rot and mildew when wet. This is particularly important because parachute harnesses need cotton webbing sections to prevent the synthetic fabric from searing on deployment. When damp, the webbing can rot if not treated.

392. Currently it is still possible to use PCP treatments in Europe as a variance to an EU Marketing & Use Directive. Because Germany has decided to implement a

national ban on the use of PCP proofing because of concerns about residual dioxin levels in treated cotton fabrics, an EC Decision has been approved. A number of EU studies are examining PCP alternatives to establish their effectiveness and their toxicity. The effects of these moves on the safety and reliability of parachute harnesses needs to be carefully monitored. A German Technical Regulation has been produced to use alternatives instead of PCP.

8.4 AREAS FOR FUTURE RESEARCH

393. In the area of pesticides use and management, there are several issues requiring additional research and work:

A. The development of non-toxic biopesticides;

B. The development of more efficient IPM systems, where cost-benefit analysis of the changes has been carried out;

C. Changing the military culture and explaining the benefits of IPM; and

D. Changing the NATO STANAG to "Standard IPM Methods."

8.5 CONCLUSIONS

394. The United States and Canada are developing IPM programs to make their use of pesticides more sustainable. The UK and Germany are also working closely with pesticide authorities to control their use of the materials. The costs of new IPM working methods and the benefits of reduced pesticide use and liabilities should be established. Greater efforts are required to change the military mindset towards IPM.

395. NATO STANAG 2048 is due for revision and should be made to shift its emphasis from chemical methods to IPM methods.

396. NATO members are seeking to eliminate the use of organochlorine and organobromine pesticides. European work may lead to an acceptable alternative to pentachlorophenol for rot-proofing natural fabrics.

8.6 RECOMMENDATIONS

397. It is recommended that the DRG should:

A. Encourage the development of IPM programs in NATO, along the lines of those being developed by the United States and Canada, and provide funding, if possible;

B. Confer with the NATO CCMS study on Environmental Management Systems to establish if the IPM approach can assist in the development of other environmental management system elements;

C. Encourage the development of IPM training programs to help NATO members to adopt more sustainable approached to pest control; and

D. Ensure that NATO STANAG 2048 is updated to cover IPM methods.

(This page intentionally left blank)

ANNEX I

REFERENCES

CHAPTER 2. PETROLEUM, OILS, AND LUBRICANTS (POL)

1. Agence Nationale de Récupération et d'Elimination des Déchets (ADEME); BP - 49 000 - Angers, France. Tel: (33) 41 20 41 20. Mr. Lecointre is a specialist in oil recycling there.

2. Alternative Fuels Demonstration, Final Report, Battelle, 24 February 1994.

3. Canadian Norm no. PCE72 (revised 8 January 1996): Marine Inboard/Outboard Engine Oil.

4. Centers, Phillip W., "Disposal of Turbine Engine Lubricants," Third Annual Air Force Worldwide Pollution Prevention Conference and Exhibition, August 29-September 1, 1994, San Antonio, Texas.

5. Centre d'Etude et de Documentation de Retraitement de l'Eau (CEDRE); Pointe du Diable, BP 72 - 29280 - Plouzané, France. Tel: (33) 98 49 12 66.

6. Deroin, Philippe, "Vers la voiture autonettoyante," L'usine nouvelle, 20 April 1995, no. 2499.

7. Elf Aquitaine Paris; Tour Elf, 92090 - Paris-La Défense, France. Tel: 44 21 72. Mr. Bernard Tramier is the environmental group director there.

8. Goetz, F. E. and M. P. Huxley, Overview of Bioremediation Applications, Institute for Defence Analyses 1996.

9. Information on RAF policy for the prevention and control of oil prevention, provided by Squadron Leader David Honeyman.

10. Institut Français du Pétrole (IFP), Biotechnology Department; 1-4, avenue de Bois Préau, BP 311 - 92500 - Rueil Malmaison, France. Tel: (33-1) 47 52 68. Points of contact at the Institut are: Mr. Claude Gatelier, research main engineer, Mr. Jean-Paul Vandecasteele, research chief engineer; Mr. Lassau has the patent for the oilproof concrete.

11. Kauffman, Robert E. et al., "Lubricant Segregation for Recycling and Reuse," Third Annual Air Force Worldwide Pollution Prevention Conference and Exhibition, August 29-September 1, 1994, San Antonio, Texas.

12. "Monitoring the Tinker Air Force Base Alternative Fuel Fleet," Technical Progress Report no. 3, ITT Research Institute, BDM Federal (National Institute for Petroleum and Energy Research), 15 June 1993.

13. NATO PHE Working Party Environmental Questionnaire, 25 February 1993.

14. Program Environmental Choice. Canadian Norm no. PCE-01-89 (revised 5 January 1996): Automobile Engine Oil.

15. Report on the Defence Science Board Task Force on Environmental Security, 22 April 1995.

16. Savatier, François, "Hydrocarbures : pollution à retardement," La Recherche, March 1995, no. 274, vol. 26, pp. 346-347.

17. Scheromm, Pascale, "Biocarburants: Á vos marques," Biofutur, October 1991, no. 127, pp. 18-24.

18. Service Hydrographique et Océanographique de la Marine (SCHOM); 13, rue du Chatellier, BP 426 - 29275 - Plouzané, France. Tel: (33) 98 22 15 83.

19. STANAG no. 1135, Annex C, 29 April 1994.

20. STANAG no. 3747, 28 November 1994.

21. "Standards for Maintenance of Fixed Aviation Fuel Receipt, Storage and Dispensing Systems," STANAG no. 3609, 13 June 1994.

22. "Technical Guidance for the Design and Construction of Aviation and Ground Fuel Installations on NATO Airfields," STANAG no. 3784, 30 November 1992.

23. Therrien, Paul R., "Alternative Fuels," Third Annual Air Force Worldwide Pollution Prevention Conference and Exhibition, August 29-September 1, 1994, San Antonio, Texas.

24. UK MOD Petroleum Pollution Reporting System.

25. US Information provided by J. Kennedy, Office of the Under Secretary of Defence for Environmental Security, Pollution Prevention.

CHAPTER 3, MUNITIONS, ENERGETICS AND PROPELLANTS

1. Headquarters- Army Materiel Command Acquisition Pollution Prevention Support Office, Materiel Developer's Guide for Pollution Prevention, Second Edition 1994. To obtain this document, write to: United States Army Materiel Command, Attn: AMCRD-E, 5001 Eisenhower Ave., Alexandria, VA 22333-0001.

2. NAMSA Demil Legislation Study on the Effect of Environmental Protection Legislation on Ammunition Disposal, June 1995.

3. STANAG 4518, Edition 1, Second Draft, 1995.

CHAPTER 4, FIRE SUPPRESSANTS AND REFRIGERANTS

For a detailed analysis of halon, solvent and refrigeration applications, availability of alternatives, technical performance and cost issues, consult the Technical Options Committee Reports of the Montreal Protocol. These are a series of technical reports beginning in 1989, with the most recent dated 1995. These documents are available through the Montreal Protocol Secretariat at the United Nations Environment Program, Nairobi, Kenya, or from national environmental ministries.

The bibliography below provides additional information:

1. Kibert, Charles F., "Performance of Chemical and Not-in-Kind Alternatives to Halon," Wright Laboratory, US Air Force and University of Florida.

2. "Management of Ozone Depleting Substances (Chapter 6)," US Navy Environmental and Natural Resources Program Manual (OPNAVINST 5090.1B), November 1994.

3. NL Environmental Protection Policy Plan, April 1992.

4. NODNL Environmental Protection Policy Plan, November 1993.

5. Strategic Guidance and Planning for Eliminating Ozone Depleting Chemicals from US Army Applications, October 1995.

6. US Air Force Policy on Ozone Depleting Chemicals, January 1993.

7. US Air Force Weapon System Pollution Prevention Policy, August 1994.

8. US Air Force Pollution Prevention Strategy, July 1995.

9. US Clean Air Act, November 1990.

10. US Navy Ozone Depleting Substances Replacement Plan, May 1995.

The participants in the Fire Extinguishants and Refrigerants Panel, who drafted and reviewed this chapter as well, can serve as sources of information or points of contact for introduction to additional information. The list of panel participants is contained in Annex IV.

CHAPTER 5, SOLVENTS AND CLEANERS CONTAINING VOLATILE ORGANIC COMPOUNDS (VOCs)

1. MCF Newsletter, Environment Canada, March 1995.

2. 2nd International NATO/CCMS Conference: The Role of the Military in Protecting the Ozone Layer, Volumes I and II, Brussels, Belgium, 24-25 January 1994.

3. UNEP 1994 Report of the Solvents, Coatings and Adhesives Technical Options Committee, 1995 Assessment, Kenya, 1994.

CHAPTER 6, SURFACE PREPARATION AND COATINGS

1. Beitelman, Alfred D., Abrasion Resistant, Volatile Organic Compound (VOC) Compliant Coatings for Hydraulic Structures, Construction Engineering Research Laboratories, Champaign, IL, 1996. Series: USACERL REMR-EM-9.

2. Bittle, James Earle, Control of Volatile Organic Compound and Hazardous Air Pollutant emissions from Aircraft Painting Operations on US Naval Air Stations, editor: James Earle Bittle, Research Project (M.S.)--Texas A&I University, 1993.

3. Briant, C. L., Metallurgical Aspects of Environmental Failures, New York, Elsevier Science Pub. Co., 1985. ISBN 0444424911.

4. Emerging Technology for Bioremediation of Metals, edited by Jeffrey L. Means and Robert E. Hinchee, Boca Raton: Lewis Publishers, c1994. ISBN 156610085X.

5. Ertan-Lamontagne, Marc C., Evaluation of Polymer Coated Attenuated Total Reflection (ATR) Elements for the Analysis of Organic Compounds in Aqueous Solution, Thesis (Ph.D), University of New Hampshire, 1995.

6. Giddings, T. J., Reduction of Volatile Organic Compound Emissions from Industrial Coating and Impregnation of Wooden Surface, editors: T. J. Giddings, I.T. Marlowe & S. J. Richardson, UNIPUB, Luxembourg: Lanham, MD, 1994. Final report to the Commission of the European Communities.

7. Guide to Cleaner Technologies Organic Coating Replacements, Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH. September 1994. EPA/625/R-94/006.

8. Handbook of Experimental Pharmacology, Vol. 115, editors: Robert A. Goyer and M. George Cherian, Springer-Verlag, 1995.

9. United States, Dept. Of Energy, Office of Technology Development, Heavy Metals Contaminated Soil Project, Resource Recovery Project, and Dynamic Underground Stripping Project Technology Summary, Washington, DC, US Dept. of Energy, 1994. DOE/EM-0129P.

10. Hahn, Wilfred J., Evaluation of Alternatives to Toxic Organic Paint Strippers, editors: Wilfred J. Hahn and P. O. [i.e. P.P.] Werschulz, US Environmental Protection Agency, Water Engineering Research Laboratory, Cincinnati, OH, 1986. EPA/600/62-86/063.

11. Heavy Metals in an Estuarine Ecosystem, 1995, editor: Paul Wright, Thesis (Ph.D.)--University of Essex, 1996.

12. Horie, C. V., Materials for Conservation: Organic Consolidants, Adhesives, and Coatings, editor: C. V. Horie, Butterworths, London; Boston, 1992.

13. Huang ,Chin P., Concurrent Removal of Toxic Heavy metals and Organic Substances by Activated Carbon Process from Contaminated Groundwater, editor: C. P. Huang (Department of Civil Engineering, University of Delaware). Prepared for Geological Survey, Reston, VA--Cover. July 20, 1983-September 30, 1984.

14. International Conference in Organic Coatings Science and Technology (19th: 1993: Athens, Greece), XIXth International Conference in Organic Coatings Science and Technology: Proceeding 19, 12-16 July 1993, Athens, Greece.

15. International Conference in Organic Coatings Science and Technology (20th: 1994: Athens, Greece), XXth International Conference in Organic Coatings Science and Technology: Proceedings 20, 4-8 July 1994, Athens, Greece.

16. International Conference on Heavy Metals in the Environment (10th: 1995, Hamburg, Germany), editors: R. D. Wilken, U. Forstner, A. Knochel, CEP Consultants, Edinburgh, 1995.

17. Leach, Thomas R., Investigation of Low volatile Organic Compound Coatings and methods for Finishing Wood Substrates: Final Report, editor: Thomas R. Leach and Larry K. Sibik, Minnesota Office of Waste Management, December 11, 1992.

18. Lewis, Peter A., Organic Pigments, 2nd edition, Federation of Societies for Coatings Technology, Blue Bell, PA, USA, 1995.

19. Manual on Determination of Volatile Organic Compound (VOC) Content in Paints, Inks, and Related Coating Products, editor: J. John Brezinski, 2nd edition, ASTM, Philadelphia, PA, 1993.

20. "Metal Contamination Aquatic Sediments," editor: Herbert E. Allen, 1995. ISBN 1-57504-010-7.

21. Metal Finishing: Organic Finishing Guidebook and Director Issue for 1994, Elsevier, New York.

22. Metal Statistics: The Statistical Guide to North American Metals, American Metal Market, New York, 1995.

23. Metallic Materials Specification Handbook, Fourth Edition, editor: Robert B. Ross, New York: Chapman & Hall, 1992.

24. Metals & Alloys in the Unified Numbering System: With a Description of the System and Cross Index of Chemically Similar Specifications, 6th Edition., Warrendale, PA: Society of Automotive Engineers; (Philadelphia): American Society for Testing and Materials, c1993. ISBN 1560913142.

25. Metals Handbook, Ninth Edition, ASM International, Materials Park, OH, 1989.

26. American Society for Metals, Metals Handbook, 10th Edition., Vol. 2, Metals Park, Ohio, 1990.

27. American Society for Testing and Materials, 1995 Annual Book of ASTM Standards, Section 2, Nonferrous Metal Products, ASTM Standard; 02.04, Philadelphia, PA, 1995.

28. Northeim, Coleen M., Use of Surface-Coating-Free Materials for Reduction of Volatile Organic Compound Emissions from Coating Operations, editors: Colleen M. Northeim, Mary W. Moore, and Michael Kosusko, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1992. EPA/600/A-92/214. PB93-106839.

29. Organic coatings: 53rd International Meeting of Physical Chemistry: Ministere de la Recherche, Paris, France, January 1995, editor: Pierre-Camille Lacaze.

30. Petreanu, John P., In Situ Vitrification of Lead Oxide Contained in Lead Based Organic Coatings Using Powder Flame Spray Technology, editor: John P. Petreanu, Thesis (M.S.)--University of Illinois at Urbana-Campaign, 1993.

31. Properties and Selection--Irons, Steels, and High-Performance Alloys, 10th Edition, ASM International, Materials Park, OH, 1990.

32. Recycling--Nonferrous Metals, editor: US Department of the Interior, Bureau of Mines, Washington, DC, 1991.

33. Shin, Hyun-Moo, Chemical Behavior of Selected Toxic Heavy Metals in Soils, Thesis (Ph.D.)--University of Delaware, 1996. Principal faculty advisor: Chin-Pao Huang, Dept. of Civil Engineering.

34. Sjoqvist, Tore, Soil Biochemical and Microbial Activities as Affected by Heavy Metals and Liming, 1995. Based on four previously prepared papers reprinted here. Thesis (Ph.D.)--Sveriges Lantbruksuniversitet, Swedish University of Agricultural Sciences, Dept. of Chemistry, 1996.

35. TerMaath, Stephen Grant, Heavy Metals Removal by Sulfide Precipitation, Coagulation and Filtration, Thesis (M.S. in Environmental Health Engr.)--University of Texas at Austin, Vita, 1974.

36. Wicks, Zeno W., Organic Coatings: Science and Technology, editors: Zeno W. Wicks, Jr., Frank N. Jones, S. Peter Pappas, Wiley, New York, Chichester, 1992.

37. Wolbach, C. D., Reduction of Total Toxic Organic Discharges and VOC Emissions from Paint Stripping Operations Using Plastic Media Blasting, editors: C.D. Wolbach and C. McDonald, United States Environmental Protection Agency, Water Engineering Research Laboratory, Cincinnati, OH, 1987. EPA/600/S2-87/014.

CHAPTER 7. SHIPBOARD SOLID AND LIQUID WASTE

1. The Allied Maritime Environmental Protection Publication 7 (AMEPP 7), Glossary of Terms and Definitions Used in the AMEPP Series, Special Working Group (SWG)/12, NATO, 1994.

2. International Convention for the Prevention of Pollution from Ships (MARPOL). Annexes I, IV (pending), and V. Original document approved in 1973; document amended in 1978.

3. The Allied Maritime Environmental Protection Publication 2 (AMEPP 2), National Navy Regulations for the Disposal of Waste, Second edition, SWG/12, NATO, September 1994.

4. Speer, Paul E. and Burnham C. McCaffree, RAdm. (Ret.), USN, Ship Solid Waste Store and Retrograde Study, CRM 95-138, Center for Naval Analyses, December 1995.

CHAPTER 8. PESTICIDES

1. Alternative Treatments for the Rot-Proofing of Textiles. D/RAE(F)M&S/45/1/4/2, Materials and Structures Department, DRA Farnbrough, Hants, UK, 1993.

2. The Armed Forces Management Board, Office of the Deputy Under Secretary of Defence (Environmental Security), Department of Defence Recommendations to the United States, Department of Agriculture on Military Research Requirements in Pest Management for FY97. The address for the AFMB is: Forest Glen Section, Walter Reed Army Medical Center, Washington, DC 20307-5001.

3. "Chemical Methods of Insect and Rodent Control (AMed P-3)," NATO STANAG No. 2048, 1990.

4. Council Directive, "Restrictions on the Marketing and use of Pentachlorophenol," Official Journal of the European Communities, 91/173/EEC, No. L 85/34, 5.4.91.

5. UNEP 1995 Report of the Methyl Bromide Technical Options Committee.

(This page intentionally left blank)

GLOSSARY OF TERMS AND ACRONYMS

ABS	Acetyl Butyl Styrene
AEC	Army Environmental Center
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFFF	Aqueous Film Forming Foam
AFP	Alternative Fuels Program
AFPBM	Armed Forces Pest Management Board
ALC	Air Logistics Center
AMEPP	Allied Maritime Environmental Protection Publication
AP	Aommonium Perchlorate
APE	Ammunition Peculiar Equipment (program)
APU	Auxiliary Power Unit
ARDEC	Army Armament Research, Development and Engineering Center
ARET	Accelerated Reduction/Elimination of Toxic Substance
ARPA	Advanced Research Projects Agency
ARTI	Air Conditioning and Refrigeration Technology Institute
ASHRAE	American Society for Heating, Refrigeration and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
ATD	Advanced Technology Demonstration
AVOCET	Project name of UK demilitarization technology
BAA	Broad Agency Announcement
BAR	Pressure unit; 1 BAR = 14.7 PSI
BATNEEC	Best Available Technology Not Entailing Excessive Cost
BEPO	Best Environmental Practical Option
BHR	British Hydro Research (Group)
BOD	Biological Oxygen Demand

BOSS	Bicarbonate of Soda Stripping
BPEO	Best Practical Economic Option
BRAC	Base Realignment and Closure
BRDEC	Belvoir Research, Development, and Engineering Center
BSCL	Better, Smaller, Cheaper, Lighter
C	Carbon
CAA	Chromic Acid Anodizing; also, Clean Air Act
CAD	Central Ammunition Depot
CARC	Chemical Agent Resistant Coating
CCD	Camouflage, concealment and deception
CCMS	Committee on the Challenges of Modern Society
CECOM	Communications Electronics Command
CFC	Chlorofluorocarbon
CIP	Cleaning in Process
CLCU	Closed Loop Cooling Unit
CLF	Combat Logistics Force (ship)
CMU	Compress/Melt Unit
CNAD	Committee of National Armaments Directors
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRADA	Cooperative Research and Development Agreement
CS	Lachrymatory agent
CVN	Aircraft carrier, nuclear-powered
db	decibel
DCM	Dichloromethane
DD	Destroyer
DIAJET	Registered name of UK hydro abrasive cutting technology
DNA	Defence Naval Architecture

DND	Department of National Defence
DoD	Department of Defence
DRA	Defence Research Agency
DRG	Defence Research Group
DTEO	Defence Test & Evaluation Organization
EAA	Ethylene Acrylic Acid
EAWJC	Entrainment Abrasive Water Jet Cutting
E-Coating	Electrodeposition
ECU	Environmental Control Unit
E(E)C	European (Economic) Community
EMAA	Ethylene Methacrylic Acid
EMI	Electromagnetic Interference
EMPF	Electronics Manufacturing Productivity Facility
EMS	Environmental Management System
EN	Electroless Nickel
EOD	Explosive Ordnance Disposal
EOLYS	Type of catalytic additive
EPA	Environmental Protection Agency
EPA	Environmental Protection Act
ERU	Electrolytic Recovery Unit
ETBE	Ethyl tributyl ether
EU	European Union
Eu	Eurovent
EWI	Explosive Waste Incinerator
ex-Shadwell	Former USS Shadwell, Landing Ship Dock (LSD)
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FFG	Guided-Missile Fast Frigate

FOG	Free Oil and Grease
FPD	Freeze Point Depressant
FY	Fiscal Year
GPM	Garbage Processing Machine
gpm	Gallons per minute
GWP	Greenhouse Warming Potential
H	Hydrogen
HAC	Hydro Abrasive Cutting
Halons	Halogenated Carbons
HAN	Hydroxylammonium nitrate
HAPs	Hazardous Air Pollutants
Hazmat	Hazardous Material
HBFC	Hydrobromofluorocarbon
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HCl	Hydrogen Chloride
HCN	Hydrogen Cyanide
HE	High Explosive
HFC	Hydrofluorocarbon
HFE	Hydroflouroethers
HMIP	Her Majesty's Inspectorate of Pollution
HMX	Octogen (explosive)
HRC	Halon Recycling Corporation
HS	Heat Sealer
H_2S	Hydrogen Sulfide
HSE	Health and Safety Executive
HVOF	High Velocity Oxygenated Fuel
IAPAC	Compressed Air Assisted Injection System

ICAO	International Civil Aviation Organization
ICOLP	Industry Cooperative for Ozone Layer Protection
IFEX	Impulse Fire Extinguishing Technology
IFP	Institut Francais des Petroles
ILDS	Integrated Liquid Discharge System
IMO	International Maritime Organization
IPM	Integrated Pest Management
IR	Infrared
ISO	International Standards Organization
IVDAI	Ion Vapor Deposition of Aluminum
IWTP	Industrial Wastewater Treatment Plant
JANNAF	Joint Army/Navy/NASA/Air Force
JDEP	Joint Depot Environmental Panel
JOC	Joint Ordnance Commanders
LARPS	Large Aircraft Robotic Paint Stripping
LHA	Amphibious assault ship
LRM	Large Rocket Motor
LSD	Dock-landing ship
LTPC	Low Temperature Thermite Charges
LTSS	Long-Term Scientific Study
LTT	Low Temperature Thermite
MAC	Mobile Air Conditioning System
MARPOL	International Convention on the Prevention of Pollution from Ships
MB	Methyl Bromide
MCM	Mine Counter-Measures ship
MEK	Methyl Ethyl Keytone
MIDAS	Munition Items Disposition Action System
MILSPEC	Military Specifications

MOD	Ministry of Defence
MPPRCA	Marine Plastic Pollution Research and Control Act
MPW	Medium Pressure Water
m/s	meter per second
MSDS	Marine Sanitation Devices
MTBE	methyl tributyl ether
MTH	Magnesium-Teflon-Hytemp
MTV	Magnesium-Teflon-Viton
NAMSA	NATO Maintenance and Supply Agency
NAVSEA	Naval Sea Systems Command
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defence Center for Environmental Excellence
NEPA	National Environmental Policy Act
NEQ	Net Explosive Quantity
NESHAP	National Emission Standard for Hazardous Air Pollution
NETE	Naval Engineering Testing Establishment
NFESC	Naval Facilities Engineering Service Center
NMERI	New Mexico Engineering Research Institute, University of
NIAG	NATO Industrial Advisors Group
nm	Nautical mile
NNAG	NATO Naval Armaments Group
NOC	Navy Oxygen Cleaner
NOx	Nitrogen Oxides
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
NTO	Nitrogen tetroxide
NWG	Natural Work Group
OB	Open Burning

OBIGGS	On Board Inert Gas Generating System
OBOD	Open Burning and Open Detonation
OCM	Oil Content Monitor
OD	Open Detonation
ODC	Ozone Depleting Chemical
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substance
OEL	Occupational Exposure Limits
OEM	Original Equipment Manufacturers
OPEVAL	Operations Evaluation
OSHA	Occupational Safety and Health Administration
OWS	Oily Water Separator
P2	Pollution Prevention
PAG	Polyakylene glycol
PAH	Polycyclic Aromatic Hydrocarbon
PBMA	Production Base Modernization (Picatinny)
PBX	Plastic- or Ploymer-Bonded Explosive
PCP	Pentachlorophenol
PCS	Pollution Control System
PCPL	Pentachlorophenol laureate
PFC	Perfluorocarbon, or Perfluorinated carbon
PMB	Plastic Media Beads
PMS	Preventative Maintenance System
POE	Polyolester Oil
POL	Petroleum, Oils, and Lubricants
PP	Plastics Processor
ppb	parts per billion
PPM	Plastics Processing Machine

ppm	parts per million
PS	Plastics Shredder
p.s.i	Pounds per square inch
PTFE	Polytetrafluoroethylene
PVC	Poly vinyl chloride
RAF	Royal Air Force
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, Development, Test & Evaluation
RDX	Hexogen (explosive)
RIDS	Runway Ice Detection System
R&M	Reliability & Maintainability
RN	Royal Navy
RNAD	Royal Navy Armament Depot
RON	Research Octane Number
RP	Red Phosphorous
RSP	Render Safe Procedure
SAW	Surface Acoustic Wavelength
SBAA	Sulfuric-Boric Acid Anodizing
SBIR	Small Business Innovation Research (program)
SCWO	Supercritical Water Oxidation
SEA	Service des Essences des Armees
SEFIS	Small Engine Fuel Injection System
SERDP	Strategic Environmental Research and Development Program
SF	Surface Finishing
SNAP	Significant New Alternatives Program, US Clean Air Act
SOx	Sulfur Oxides
SPT	Self Priming Topcoat
SRM	Solid Rocket Motor

STANAG	Standardization Agreement, NATO
SWG	Special Working Group
SWS	Solid Waste Shredder
TACOM	Theater Army Command
TAME	Tertioamyl methylether
TBT	Tributyl Tin
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
TEQ	Total Explosive Quantity
TNT	Trinitrotoluene
TPC	Thermoplastic Powder Coating
TPE	Thermal Plastic Elastomer (binder)
UK	United Kingdom
UNEP	United Nations Environment Program
US	United States
USAF	United States Air Force
USCG	United States Coast Guard
USDA	United States Department of Agriculture
UST	Underground Storage Tank
UV	Ultraviolet
UXO	Unexploded Ordnance
VCBT	Vacuum, Collection and Biological Treatment (system)
VCH	Vacuum, Collection and Holding (system)
VCHT	Vacuum, Collection, Holding and Transfer (system)
VMS	Volatile Methyl Siloxaner
VOC	Volatile Organic Compound
WPAFB	Wright-Patterson Air Force Base
WPM	Waste Processing Machine

WR/WD	Water Reducible/Water Dispersible

ANNEX III

DATABASES AND OTHER SOURCES OF INFORMATION

This annex lists various hard-copy publications as well as other sources of information available through the Internet pertaining to pollution prevention and other relevant environmental issues.

PUBLICATIONS

This first list covers publications on environmental issues of particular relevance to the LTSS/44 study. For those citations that are annual conference proceedings, the organizer's name and address are provided, should the reader wish to obtain copies of previous years' proceedings.

1. Aeronautical Systems Center Environmental Management Directorate, Wright Patterson Air Force Base, Ohio, Pollution Prevention in Weapon System Acquisition: A "How To" Handbook for Institutionalizing Pollution Prevention in Weapons System Acquisition, 1994.

2. Air Force Worldwide Pollution Prevention Conference and Exhibition. Annual conference since 1992. Point of contact: Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

3. The Business Roundtable, Facility Level Pollution Prevention Benchmarking Study, November 1993. Point of contact: AT&T Bell Laboratories QUEST Organization.

4. Catalogue of Specialized Solvent Uses: Sourcebook (Peer Review), Paris: United Nations Environment Program - Ozonaction Information Clearinghouse, June 1994.

5. George C. Cushnie, Jr. Pollution Prevention and Control Technology for Plating Operations, Ann Arbor, Michigan: National Center for Manufacturing Services, 1994.

6. Environmental Symposium and Exhibition. Annual conference since 1974. Point of contact: American Defence Preparedness Association's Environmental System Division, 1050 17th Street, NW, Washington, DC.

7. Hazardous Materials Management Conference. Annual conference since 1986. Point of contact: Aerospace Industries Association (AIA), 1250 I Street, NW, Washington, DC.

8. International CFC and Halon Alternatives Conference and Exhibition. Annual conference since 1990. Point of contact: International Conference on Ozone Protection Policies, P. O. Box 236, Frederick, Maryland.

9. International Workshop on Solvent Substitution. Annual conference since 1990. Point of contact: Weapons Complex Monitor Forums, 50 Green Bay Road, Box 406, Lake Bluff, Illinois.

10. NATO/CCMS. The Role of the Military in Implementing the Montreal Protocol. Williamsburg, Virginia, September 1991.

11. NATO/CCMS, The Role of the Military in Protecting the Ozone Layer, Brussels, January 1994.

12. Rigby, Review of Literature on Environmentally Conscious Design, Institute for Defence Analyses, December 1995.

13. Thiokol Corporation. TCA Replacement Selections Made by Industry, Brigham City, Utah: Thiokol Corporation, 1993.

14. US Army Acquisition Pollution Prevention Support Office, Materiel Developer's Guide for Pollution Prevention, Second edition, 1994.

15. US Army Production Base Modernization Activity, Life Cycle Readiness Division. Life Cycle Environmental Guide for Weapon Systems Project Managers, June 1995. Requests for document should be sent to: Director PBMA, ATTN: AMSMC-PBR, Picatinny Arsenal, NJ 07806-5000.

16. USEPA/ICOLP, Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning. Washington, DC: USEPA, No. EPA/400/1-94/019, October 1994.

17. USEPA/ICOLP, Aqueous and Semi-Aqueous Alternatives for CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies, Washington, DC: USEPA, No. EPA/400/1-94/016, October 1994.

18. USEPA/ICOLP, Eliminating CFC-113 and Methyl Chloroform in Precision Cleaning Operations, Washington, DC: USEPA, No. EPA/400/1-94/018, October 1994.

19. USEPA/ICOLP, Eliminating CFC-113 and Methyl Chloroform in Aircraft Maintenance Procedures, Washington, DC: USEPA, No. EPA/430/B-93/006, October 1993.

20. USEPA/ICOLP, No-Clean Soldering to Eliminate CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies, Washington, DC: USEPA, No. EPA/430/B-93/005, October 1993.

21. USEPA/ICOLP, Conservation and Recycling Practices for CFC-113 and Methyl Chloroform, Washington, DC: USEPA, No. EPA/400/1-91/017, June 1991.

22. USEPA/ICOLP, Manual of Practices to Reduce and Eliminate CFC-113 Use in the Electronics Industry, Washington, DC: USEPA, No. EPA/400/3-90/003, March 1990.

INFORMATION AVAILABLE ELECTRONICALLY

This second list provides electronic site addresses on environmental topics and the name of the organization for that site. For some, a brief description of the site is included.

Directories of Environmental Technologies and Information

1. "http://www.erin.gov.au/net/neid.html"
Australia National Environment Industries Database
From the Australia Environmental Protection Agency; includes a section on R&D section on Waste Management and Pollution Control

2. "http://www.ulb.ac.be/ceese/cds.html"
Best Environmental Directories
Lives up to its self appointed name - it is one of the best directories. From Belgium, can be viewed or downloaded in either English or French.

3. "http://pan.cedar.univie.ac.at/"
CEDAR - Central European Environmental Data Request Facility
Environmental assessment information; points to the Austrian Federal Ministry for the Environment;. in German.

4. "http://denix.cecer.army.mil/denix/denix.html"
Defence Environmental Network and Information Exchange (DENIX) for US DoD. Note: to access DENIX, you must have a password. Within DENIX, there is a pollution prevention library, which is text searchable and has eight topic areas, each with a discussion section. Other specific topics and the way to reach them on DENIX include:

(a) "http://denix.cecer.army.mil/denix/Main/Subject/Pests/subject-pests.html"
Pest Management

(b) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/TECHLIB/Electro/subject-pollution-techlib-electro.html"
Plating database

(c) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/TECHLIB/ODS/subject-pollution-techlib-ods.html"
ODS Database

(d) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/PROACT/subject-pollution-proact.html"
Air Force PRO_ACT Program

(e) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/TECHLIB/Paint/subject-pollution-techlib-paint.html"
Painting/Depainting Database

(f) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/TECHLIB/POL/subject-pollution-techlib-pol.html"
POL/Antifreeze Database

(g) "http://denix.cecer.army.mil/denix/Main/Subject/Pollution/TECHLIB/Solvent/subject-pollution-techlib-solvent.html"
Solvent Database

5. "http://echs.ida.org/"
NATO CCMS Environmental Clearinghouse Describes the several CCMS Pilot Studies in some detail.

6. "http://qqq.com/ecotech/sites/index.html"
Ecotech-Europe'95
Information about European and other environmental conferences; pointers to environmental technology sources. Go to the end of the page and find environmental technology and other information in Dutch ("http://www.xs4all.nl/~rudydok/")

7. "http://www.ra.utk.edu/eerc/"
Energy, Environment and Resources Center
Clean products and technologies from the University of Tennessee.

8. "http://www.ems.uwplatt.edu/ce/fac/dymond/enviro.html"
Environmental Engineering WWW Sites
Another excellent directory of environmental information from recycling to ozone depletion to the politics of environmentalism.

9. "http://delta.ci.uminho.pt/deb/fontes/ambiente.html"
Environmental Information Sources
A directory of environmental resources from the University of Minho in Portugal; in Portuguese or English

10. "http://www.igc.org/envlaw/"
Environmental Law Around the World
Environmental Law Alliances's environmental laws of Africa, Middle East, Europe (including former Soviet Union), the Americas as well as international treaties.

11. "http://www.mbnet.mb.ca/linkages/"
Environmental Linkages Home Page
The International Institute for Sustainable Development's guide to international treaties and conventions.

12. "http://www.missouri.edu/~c632908/environmental.html"
Environmental Navigator, Missouri State
Directory of environmental sites and environmental search engine from the University of Missouri.

13. "http://www.geopac.com/"
Environmental Professional's Homepage
A well laid out directory by subject area lets you read a synopsis of a site's content before visiting. Includes technically oriented subject areas.

14. "http://www.epa.gov/"
Environmental Protection Agency WWW Server
The US EPA's home page with a wide range of technical, regulatory, legal & policy topics. Some of the particular entries are as follows (and may be included in other sections of this annex as well):

(a) "http://www.epa.gov/ada/kerrlab.html"
EPA Kerr Lab; Nat'l Risk Mgt Research Lab

(b) "http://www.epa.gov/attic/attic.html"
ATTIC BBS

(c) "http://www.epa.gov/consrv-news/"
EPA Conservation Newsletter

(d) "http://www.epa.gov/docs/GCDOAR/Methane.html"
EPA Methane Reduction Outreach Programs

(e) "http://www.epa.gov/docs/IRM.Strategy/affirm/affirm_a.html"
EPA IRM & Mission Connection

(f) "http://www.epa.gov/docs/IRM.Strategy/straplan/straplan.html"
EPA IRM Strategic Plan

(g) "http://www.epa.gov/docs/OIG.html"
EPA Office of the Inspector General

(h) "http://www.epa.gov/docs/OSWERSuper/"
Superfund Program

(i) "http://www.epa.gov/docs/ozone/index.html"
EPA & Ozone Depletion

(j) "http://www.epa.gov/docs/ozone/title6/usregs.html"
US Ozone Protection Regulations

(k) "http://www.epa.gov/enviro/html/cerclis/cerclis_overview.html"
CERCLA Information System

(l) "http://www.epa.gov/Region2/"
EPA Region 2 Public Access Services

(m) "http://www.epa.gov/R5Super/home-s.html"
EPA Region 5 Superfund Home Page

(n) "http://www.epa.gov/Rules.html"
EPA Rules, Regulation and Legislation

14. "http://www.unep.ch/"
Geneva Executive Center
Links to United Nations Environment Programme topics

15. "http://www.brooks.af.mil/HSC/EM/links.html"
HSC/EM Environmental Links to the Internet
US Force's Human Systems Center's directory to environmental sites with brief explanations of the sites contents. Includes technical, policy and educational information.

16. "http://www.gwu.edu/~greenu/"
National Enviromental Information Resource Center
Environmental education and technology sites from George Washington University and the US EPA.

17. "http://www.ornl.gov/publications/core/stand.html"
Oak Ridge National Laboratory
Pollution Prevention technologies; building and manufacturing subjects.

18. "http://www.nsnet.com/"
NSnet! (Maritime Industry)
Look under research and development for environmental technologies for the maritime industry. Also includes address for maritime environmental discussion group.

19. "http://home.navisoft.com/rcpinc/rcpinc/title.html"
Regulatory Compliance Professionals
Technical information on air pollution, hazardous and solid waste, water and others.

20. "gopher://unep.unep.no:70/11/un"
UNEP Gopher

21. "http://enviro.navy.mil/"
US Navy Environmental Home Page
Information about the US Navy programs; Cleanup, compliance, pollution prevention and conservation.

Information on Specific Compounds

The following two sites can be accessed to obtain Material Safety Data Sheets (MSDS) for specific substances.

1. "http://research.nwfsc.noaa.gov/msds.html"
   MSDS

2. "gopher://atlas.chem.utah.edu/11/MSDS"
   MSDS Gopher

3. "http://rcr.ioc.ac.ru/rcr.html"
   Russian Chemical Reviews Archive Home Page
   Information about specific chemicals.

Ozone Depletion and Air Pollution Information

1. "http://www.awma.org/"
   Air & Waste Management Association
   Information on environmental conferences, publications and issues.

2. "http://www.aqmd.gov/"
   South Coast Air Quality Management District WWW Home Page
   The government regulatory agency responsible for southern California, where 14 million people breath some of the dirtiest air in the US. Technical information on control of air pollution.

3. "http://www.epa.gov/docs/ozone/index.html"
   EPA & Ozone Depletion
   The US EPA's information page on stratospheric ozone depletion.

4. "http://www.idss.ida.org/"
   ODS DATABASE
   Technical information on ozone depleting substances, their uses and alternatives.

5. "http://www.epa.gov/docs/ozone/title6/usregs.html"
   US Ozone Protection Regulations
   Title 6 of the US Clean Air Act and which implements US obligations under the Montreal Protocol; and other rules and regulations controlling ODS.

6. "http://unep.unep.no/unep/secretar/ozone/about.html"
   UNEP Ozone Web Page
   The Home Page of the United Nations Environment Programme Ozone Secretariat.

ISO 14000

1. "http://www.iso14000.com/"
   ISO 14000 InfoCenter

2. "http://www.stoller.com/"
   ISO 14000 (Stoller Site)

3. "http://www.iso.ch/"
   Welcome to ISO Online

Pollution Prevention Information

1. "http://www.epa.gov/docs/GCDOAR/OAR-APPD.html"
   EPA Atmospheric Pollution Prevention Division
   US EPA's voluntary programs to prevent air pollution; heavy emphasis on greenhouse gases and the Climate Change Action Plan.

2. "http://es.inel.gov/comply/sector/index.html"
   EPA's Sector Notebooks
   Pollution prevention technologies tailored for specific industry sectors from the US EPA.

3. "http://es.inel.gov/new/funding/serdp/p2prj007.html"
   Integrated Expert Solvent Substitution Database

4. "http://wastenot.inel.gov/envirosense/program/iniative/iniative.html"
   EPA Pollution Prevention and Other Initiatives
   US EPA source for toxic inventory reporting, technical exchange, review of source reduction techniques, and other PP information.

5. "http://es.inel.gov/index.html"
   EnviroSense Pollution Prevention Page
   Pollution prevention technologies from the Idaho National Laboratory

6. "http://www.fedworld.gov/environ.html"
   FedWorld Environmental Pollution and Control
   Air pollution, pesticides, water pollution and health information.

7. "http://es.inel.gov/program/p2dept/p2dept.html"
   Federal Government P2 and Other Environmental Activities and Pronouncements

Excellent source; US Government Agency pollution prevention programs, including DoD.

8. "http://www.ce.cmu.edu/GreenDesign/"
Green Design Initiative Home Page
Carnegie Mellon University program on the cost effectiveness of designing products, processes and facilities for environmental performance.

9. "gopher://gopher.pnl.gov:2070/1/.pprc"
Pacific Northwest Laboratory Pollution Prevention Research Clearinghouse Gopher
PNL's pollution prevention database; technically oriented; lots of R&D information.

10. "http://web.mit.edu/ctpid/www/tbe/"
Technology, Business and Environment at MIT
Design for the Environment and Industrial Ecology information from MIT.

Recycling Information

1. "http://www.doe.ca/ecocycle/"
Ecocycle (Environment Canada)

2. "http://www.webcom.com/~infoserv/customer/nora/welcome.html"
National Oil Recyclers Association

3. "http://www.earthcycle.com/g/p/earthcycle//"
NMEN: A Free Recycling Marketplace

Pesticides

1. "http://www.ewg.org/Weed_Killer/Weed_home.html"
Weed Killers By The Glass

OTHER ELECTONIC SITES

1. "ftp://coombs.anu.edu.au/coombspapers/otherarchives/asian-studies-archives/vietnam-archives/environment-law/english/"
Directory of Asian Country Environmental Information

2. "gopher://gaia.info.usaid.gov:70/11/prot_env/dcs"
EPA Country Environmental Studies Gopher

3. "gopher://www.epa.gov/11/Initiatives/CSI/"
EPA Common Sense Initiative Gopher

4. "http://129.229.1.100/ceq/ceq.html"
Council on Environmental Quality

5. "http://atsdr1.atsdr.cdc.gov:8080/atsdrhome.html"
ATSDR - Home Page

6. "http://cdiac.esd.ornl.gov/cdiac/"
Carbon Dioxide Information Analysis Center (CDIAC)

7. "http://earth1.epa.gov/OSWRCRA/hazwaste/permit/"
EPA Permits and Permitting

8. "http://envirolink.org/orgs/index.html"
Environmental Organizations

9. "http://etd.pnl.gov:2080/hydroweb.html"
Hydrology-Related Internet Resources

10. "http://gcmd.gsfc.nasa.gov/"
Global Change Master Directory

11. "http://gwint1.gwi.memphis.edu/"
Ground Water Institute

12. "http://home.aol.com/sonicspeed"
Sonicspeed's Environmental Pointers

13. "http://info.cas.org/ONLINE/CATALOG/descript.html"
STN Database Catalog

14. "http://infotree.nl/ecotech/sites/index.html"
Ecotech-Europe'95

15. "http://iridium.nttc.edu/env_dod.html"
Environmental Technologies From DOD

16. "http://iridium.nttc.edu/nttc.html"
The National Technology Transfer Center Home Page (NTTC)

17. "http://ivory.nosc.mil/~saundel/default.html"
Navy South Division Environmental Department

18. "http://kaos.erin.gov.au/other_servers/other_servers.html"
Other Environmental Information Servers

19. "http://nvcc.nvc.cc.ca.us/et/"
Environmental Technology Education

20. "http://open.igc.org/svtc/"
Silicon Valley Toxics Coalition

21. "http://rdpsvr.nrl.navy.mil/"
Upper Atmospheric Physics Branch, Code 7640

22. "http://solstice.crest.org/common/crestinfo.html"
Solstice: CREST Information

23. "http://solstice.crest.org/"
Solstice: Sustainable Energy and Development Online!

24. "http://users.aol.com/dowser/"
Bannister Research & Consulting - World Wide Water

25. "http://www.acq.osd.mil/es/"
USD(A&T) Economic Security Home Page

26. "http://www.acq.osd.mil/es/std/stdhome.html"
Standardization Program Division WWW Home Page

27. "http://www.assumption.edu/html/academic/conf/iicecall.html"
International Interdisciplinary Conference on the Environment

28. "http://www.awwa.org/"
American Water Works Association

29. "http://www.cahwnet.gov:80/epa/"
California EPA Home Page

30. "http://www.cdi.org/"
Center for Defence Information

31. "http://www.cedar.univie.ac.at/arch/"
CEDAR Mailing List Archives

32. "http://www.cfe.cornell.edu/wei/weihome.html"
Work & the Environment Initiative; Cornell

33. "http://www.dtic.dla.mil:80/defenselink/"
DefenseLINK

34. "http://www.dtic.dla.mil/envirodod/envirodod.html"
DoD Environmental Restoration Electronic Bulletin Board

35. "http://www.dupont.com/corp/r-and-d/environ/environ.html"
DuPont Safety, Health and the Environment 1994 Progress Report

36. "http://www.earthisland.org/ei/"
Earth Island

37. "http://www.echs.ida.org/"
Environmental Clearinghouse (of information on NATO environmental studies)

38. "http://www.econet.apc.org/ciel/index.html"
Center for International Environmental Law (CIEL) Home Page

39. "http://www.eea.dk"
European Environment Agency

40. "http://www.enn.com/navigatr/topic/legal.htm"
Environmental Network News

41. "http://www.enviroindustry.com/opportunities.html"
Environmental Industry Web Site: Business Opportunities

42. "http://www.envirolink.org/pbn/gmj/index.html"
greenmoney journal

43. "http://www-ep.es.llnl.gov/www-ep/esd.html"
LLNL Earth Sciences Division Home Page

44. "http://www.epri.com/org/OrgOverview.html"
Edison Power Research Institute Organizational Overview

45. "http://www.essential.org/orgs/Ozone_Action/5.html"
Ozone Action Programs And Publications WWW Server

46. "http://www.ewg.org/"
Environmental Working Group

47. "http://www.fireweb.com/"
FireWeb Home Page

48. "http://www.foe.co.uk/pubsinfo/infosyst/other_services.html"
Environmental Information Services on the Internet

49. "http://www.fplc.edu/tfield/pausten.html"
Retrospective on US Health Risk Assessment

50. "http://www.gcdis.usgcrp.gov/"
GCDIS Homepage

51. "http://www.govtech.net/"
Government Technology's Home Page

52. "http://www.halcyon.com/cleanh2o/ww/welcome.html"
The World-Wide Web Virtual Library: Wastewater Engineering

53. "http://www.halcyon.com/datacore/eci/"
Environmental Concerns Inc. Homepage

54. "http://www.halcyon.com/fkroger/wn.html"
World Neighbors Home Page

55. "http://www.halcyon.com/NAFED/HTML/Welcome.HTML"
National Association of Fire Equipment Distributors

56. "http://www.icel.org"
International Cooperative for Environmental Leadership

57. "http://www.iue.it/"
European University Institute (Florence, IT)

58. "http://www.law.cornell.edu/topics/environmental.html"
US Environmental Law

59. "http://www.mfaa.com/un/gefrii/rblac/reg/portfolio.html"
Gateway to GEF: Latin America and the Caribbean

60. "http://www.missouri.edu/~c632908/environmental.html"
Environmental Navigator, Missouri State

61. "http://www.mod.uk"
UK Government - MOD

62. "http://www.nando.net/ads/ckbus/RAinfo/reglink1.html"
The Regulatory Affairs Information Home Page

63. "http://www.navy.mil/"
Navy OnLine Home Page

64. "http://www.nist.gov/"
National Institute of Standards and Technology WWW - Home Page

65. "http://www.netpath.net/kidde/"
Walter Kidde Home Page</A>

66. "http://www.nosc.mil/planet_earth/info.html"
Planet Earth Home Page

67. "http://www.nttc.edu/environmental.html"
Environmental Technology Gateway

68. "http://www.nwf.org/"
The Progressive Directory @igc

69. "http://www.quiknet.com/globalff/globalfu.html"
Global Futures Homepage

70. "http://www.tribnet.com/environ/SEJOURN.HTM"
Society of Environmental Journalism

71. "http://www.usgcrp.gov/ipcc/"
IPCC Working Group II Home Page

72. "http://www.usgs.gov/"
United States Geological Survey Home Page

73. "http://www.voyagepub.com/publish/stories/allstory.html"
Science & the Environment - October Stories

74. "http://www.w3.org/hypertext/DataSources/WWW/Servers.html"
World-Wide Web Servers: Summary

75. "http://www.waterweb.com/"
Water Web (tm) Home Page

76. "http://www.waterwiser.org/"
Welcome To WaterWiser

77. "http://www.wes.army.mil/serdp/home.html"
Strategic Environmental Research & Development Program

78. "http://www.wpi.edu/~fpe/nfpa.html"
The National Fire Protection Association

79. "http://www.wqa.org/"
Water Quality Association WebSite

80. "http://www.yahoo.com/Environment_and_Nature"
Yahoo - Environment and Nature

ANNEX IV

LIST OF PARTICIPANTS AT THE LTSS/44 MULTINATIONAL EXERCISE

DIRECTOR

TUMARKIN, Dr. Joel E. *
Institute for Defence Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

Tel: 1-703-845-2568
Fax: 1-703-845-6722
E-mail: jtumarkin@ida.org

NATO POINT OF CONTACT

STAMATOPOULOUS, Mr. Dmitris
Secretary, Panel 1
Defence Research Group
Defence Support Division
NATO Headquarters
B-1110 Brussels
BELGIUM

Tel: 32-2-728-4286
Fax: 32-2-728-4103

* Members of LTSS/44.

CANADA

BERTHIAUME, Mr. Holmer
DRC 4
National Defence Headquarters
MGen George R. Pearkes Bldg.
101 Colonel By Drive
Ottawa, ON K1A 0K2
CANADA

Tel: 1-613-945-7556
Fax: 1-613-992-9422

BESHAI, Ms. Joan
DLESS 5 Hazardous Materials
National Defence Headquarters
MGen George R. Pearkes Bldg.
101 Colonel By Drive
Ottawa, ON K1A 0K2
CANADA

Tel: 1-819-997-9835
Fax: 1-819-994-4246

BOULAY, Capt. Rodrigue
DAES 3-3
National Defence Headquarters
MGen George R. Pearkes Bldg.
101 Colonel By Drive
Ottawa, ON K1A 0K2
CANADA

Tel: 1-819-997-4079
Fax: 1-819-997-3524

* Members of LTSS/44.

BOWERS, Capt. Christopher
DGAEPM Environmental Officer
Director General Aerospace Equipment
Program Management
National Defence Headquarters
MGen George R. Pearkes Bldg.
101 Colonel By Drive
Ottawa, ON K1A 0K2
CANADA

Tel: 1-613-990-5879
Fax: 1-613-998-6922

DICKOUT, Ms. Sue
DMSS 2-4-2
National Defence Headquarters
MGen George R. Pearkes Building
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
CANADA

Tel: 1-819-994-8649
Fax: 1-819-994-8873
E-mail: sdickout@dmds.dnd.ca

MONAHAN, Capt. Bruce
DPM CE 5
National Defence Headquarters
MGen George R. Pearkes Bldg.
101 Colonel By Drive
Ottawa, ON K1A 0K2
CANADA

Tel: 1-819-994-9627
Fax: 1-819-994-9601

* Members of LTSS/44.

REIMER, Dr. Kenneth *
Director, Environmental Sciences Group
Dept. of Chemistry and Chemical
Engineering
Royal Military College of Canada
Kingston ON K7K 5L0
CANADA

Tel: 1-613-541-6000 x6161
Fax: 1-613-541-6596
E-mail: reimer-k@rmc.ca

ROGERS, Ms. Jennifer *
Environmental Sciences Group
Dept. of Chemistry and Chemical
Engineering
Royal Military College of Canada
Kingston ON K7K 5L0
CANADA

Tel: 1-613-541-6000 x6562
Fax: 1-613-541-6596
E-mail: rogers-j@rmc.ca

FRANCE

LECARPENTIER, Mr. Christian
Chief Chemist Pharmacist
Etat-major de la marine
2, Rue Royale
00350 Armees
FRANCE

Tel: 33-1-42-92-19-42
Fax: 33-1-42-92-18-13

* Members of LTSS/44.

COPPET, Dr. Lucien *
Chief Chemist Pharmacist
Study Center of Le Bouche
BP 3
91710 Vert le Petit
FRANCE

Tel: 33-1-69-908-255
Fax: 33-1-64-935-266

GOASDOUE, Mr. Jean-Luis *
Chemist Pharmacist
Study Center of Le Bouchet
BP 3
91710 Vert le Petit
FRANCE

Tel: 33-1-69-908-259
Fax: 33-1-64-935-266

GERMANY

FLECK, Mr. Wilhelm
German Liaison Office for Defence Materiel
Reston, VA 22091-4394

Tel: 1-703-715-8162
Fax: 1-703-735-8399

GRUNERT, Mr. Christian *
Federal Office for Defence Technology and Procurement
BWB-AT II 1
Mail Stop 7360
Koblenz 56057
GERMANY

Tel: 49-261-400-2811
Fax: 49-261-400-3504

* Members of LTSS/44.

OTTEN, Mr. Christoph
Federal Office for Defence Technology and Procurement
BWB- SG III 3
Mail Stop 7360
Koblenz 56057
GERMANY

Tel: 49-261-400-4053
Fax: 49-261-400-4339 or 4464

SIMEIT, Mr. Christian
Federal Office for Defence Technology
and Procurement
BWB- ZA III 4
Mail Stop 7360
Koblenz 56057
GERMANY

Tel: 49-261-400-5548
Fax: 49-261-400-5545

NETHERLANDS

BOSSARD, Mr. Rien
Directorate Material
Royal Netherlands Navy
Dept. of Platform Systems
P. O. Box 20702
2500 ES The Hague
NETHERLANDS

Tel: 31-70-316-3115
Fax: 31-70-316-3131

* Members of LTSS/44.

HOFSTEDE, Mr. Eric
Materials Department Royal Netherlands
Army/BVC, PgU and gVg
P. O. Box 90822
2509 EV The Hague
NETHERLANDS

Tel:: 31-70-316-4618
Fax: 31-70-316-7441

JANSSEN, Mr. Anton *
Directorate of Material
Royal Netherlands Navy
Dept. of Platform Systems
P. O. Box 20702
2500 ES The Hague
NETHERLANDS

Tel: 31-70-316-3114
Fax: 31-70-316-3131

SPAIN

LARBURU, Cdr. José *
Chief of Section
Naval Engineering, STCM
PIO XII, 83
28036 Madrid
SPAIN

Tel: 34-1-379-5486
Fax: 34-1-379-5493

* Members of LTSS/44.

UNITED KINGDOM

HONEYMAN, Sqn Ldr David
Pet Plans 3
Room 1383
MOD Main Building
London SW1A 2HB
UNITED KINGDOM

Tel: 44-171-218-1878
Fax: 44-171-218-3469

MARSHALL, Dr. Greg *
MOD Environment Unit
Room 2/78
Metropole Building
Northumberland Ave.
London WC2N 5BL
UNITED KINGDOM

Tel: 44-171-218-9158
Fax: 44-171-218-4609
E-mail: marshall@cispe.mod.uk

WILKINSON, Major Adrian
Head of Demilitarisation
DTEO Shoeburyness
New Ranges
Blackgate Road
Shoeburyness
Essex SS3 9SR
UNITED KINGDOM

Tel: 44-170-229-2271
Fax: 44-170-229-2868

* Members of LTSS/44.

UNITED STATES

ALIG, Mr. Craig
Carderock Division (Code 63)
Naval Surface Warfare Center
Annapolis, MD 21402-5067

Tel: 1-410-293-2773
Fax: 1-410-293-2530

ANSELL, Mr. Ed
Demil Technology Office
US Army Defence Ammunition Center and School
ATTN: SMCAC-TD
Savanna, IL 61074-9639

Tel: 1-815-273-8081 or -8084
Fax: 1-815-273-8717
E-mail: egansell@savanna-emh1.army.mil

BRESLIN, Mr. Dave
Naval Sea Systems Command (SEA03V24)
Environmental Engneering Group Code: CO3V2
National Center Bldg 3
2531 Jefferson Davis Hwy
Arlington, VA 22202

Tel: 1-703-602-9025 x240
Fax: 1-703-602-9025

BRYCE, Mr. Dexter
Geo-centers, Inc.
1755 Jefferson Davis Highway
Crystal Square 5
Suite 910
Arlington, VA 22202

Tel: 1-703-769-1806
Fax: 1-703-769-1885

* Members of LTSS/44.

BUSH, Mr. Thomas
AMCRD
HQ AMC
ATTN: AMCRD-E
5001 Eisenhower Avenue
Alexandria, VA 22333-0001

Tel: 1-703-617-5941
Fax: 1-703-617-5146

CLARK, Ms. Susan *
Institute for Defence Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

Tel: 1-703-845-2166
Fax: 1-703-845-2255
E-mail: sclark@ida.org

CYR, Ms. Catharine
US Navy Chief of Naval Operations (N451I)
The Pentagon, Room 4C456
Washington, DC 20350-2000

Tel: 1-703-602-5335
Fax: 1-703-602-4642

DAY, Mr. Alvin
HQ AFCESA/CESM
139 Barnes Drive, Suite 1
Tyndall Air Force Base, FL 32403-5319

Tel: 1-904-283-6357
Fax: 1-904-283-6219
E-mail: daya@afcesa.af.mil

* Members of LTSS/44.

FORDHAM, Mr. Wayne
HQ AFCESA/CESM
139 Barnes Drive, Suite 1
Tyndall Air Force Base, FL 32403-5319

Tel: 1-904-283-6465
Fax: 1-904-283-6219

GAWENIS, Mr. Chuck
Corpus Cristi Army Depot (CCAD)
MS 23
308 Crecy Street
Corpus Cristi, TX 78419-5260

Tel: 1-512-939-4170
Fax: 1-512-937-1173

GOLDBERG, Mr. Robert
US Army PBMA
AMSIO-IRA-W
Picatinny Arsenal, NJ 07806-5000

Tel: 1-201-724-4078
Fax: 1-201-724-2314
E-mail: regold@pica.army.mil

HERRING, Mr. Carroll
HQ AFMC/ENBE
4375 Childlaw Road, Suite 6
Wright-Patterson Air Force Base, OH 45433-5006

Tel: 1-513-257-6448
Fax: 1-513-257-0841

* Members of LTSS/44.

IHRKE, Col. Paul W.
DoD Explosives Safety Board
2461 Eisenhower Avenue
Alexandria, VA 22331-0600

Tel: 1-703-325-8889
Fax: 1-703-325-6227
E-mail: ihrkepa@ddesb.acq.osd.mil

KINZIE, Mr. Richard
US Air Force Corrosion Program Office
WL/MLS-OL
420 2nd Street, Ste 100
Robins AFB, GA 31098

Tel: 1-912-926-3284
Fax: 1-912-926-6619

KOSS, Mr. Larry
Director, Special Working Group 12
OPNAV, N452
Crystal Plaza #5
Room 654
2211 Jefferson Davis Highway
Arlington, VA 22244-5108

Tel: 1-703-602-2562
Fax: 1-703-602-5547

LEWIS, Mr. James Reginald
ASC/VXE
102 W. "D" Avenue, Suite 168
Eglin Air Force Base, FL 32542-6807

Tel: 1-904-882-9435 x2033
Fax: 1-904-882-1098

* Members of LTSS/44.

MCCAFFREE, RAdm. (Ret.) Burnham (Mike)
Institute for Defence Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

Tel: 1-703-845-2399
Fax: 1-703-845-6722

MCKENNA, Lt. Col. Robert
Armed Forces Pest Management Board
Forest Glen Section, WRAMC
Washington, DC 20307-5001

Tel: 1-301-295-7476
Fax: 1-301-295-7473

MOREHOUSE, Mr. Edward (Tom)
Institute for Defence Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

Tel: 1-703-845-2442
Fax: 1-703-845-6722
E-mail: emorehou@ida.org

MULLENHARD, Mr. Peter
Manager, US Navy CFC & Halon Clearinghouse
Geo-Centers
1755 Jefferson Davis Highway
Suite 910
Arlington, VA 22202

Tel: 1-703-769-1899
Fax: 1-703-769-1885

* Members of LTSS/44.

PALMISANO, Dr. Anna
Acting Director
Biological & Biomedical Science and Technology
Department of the Navy
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5660

Tel: 1-703-696-4986
Fax: 1-703-696-1212

POK, Ms. Michelle
SA-ALC/TIEM
450 Quentin Roosevelt Road
Kelly AFB, TX 78253

Tel: 1- 210-925-7391
Fax: 1-210-925-4916
E-mail: mpok@sadis05.kellyafb.mil

PULLEY, Mr. David F.
Naval Air-Warfare Center
Aircraft Division
MS3, Building 2188
Patuxent River, MD 20670

Tel: 1-301-342-8050
Fax: 1-301-342-8062

RODRIGUEZ, Mr. Anthony
Carderock Division
Naval Surface Warfare Center
Annapolis, MD 21402-5067

Tel: 1-410-293-3526
Fax: 1-410-293-4874

* Members of LTSS/44.

RUDROFF, Mr. Jim
US Dept. of Navy
Naval Sea Systems Command
ATTN: NAVSEA
Code: 03M (J. Rudroff)
2531 Jefferson Davis Hwy
Arlington, VA 22242-5160

Tel: 1-703-602-0216 x122
Fax: 1-703-602-0247
E-mail: rudroff_james@hq.navy.navsea.mil

SACHAR, Mr. Thomas
US Army, ARDEC
Industrial Ecology
Building 172
Picatinny Arsenal, NJ 07806-5000

Tel: 1-201-724-2364
Fax: 1-201-724-6759

ZANOWICZ, Mr. Robert
USA/(ARDEC) Army Research, Development
& Engineering Center
Attn: AMSTA-AR-ET
Picatinny Arsenal, NJ 07806-5000

Tel: 1-201-724-5744
Fax: 1-201-724-6759

* Members of LTSS/44.

(This page intentionally left blank)

* Members of LTSS/44.

COMPOSITION OF WORKING GROUPS

POL

*COPPET, Dr. L.
DAY, Mr. A.
DICKOUT, Ms. S.
HOFSTEDE, Mr. E.
HONEYMAN, Sqn Ldr D.
JANSSEN, Mr. A.
MONAHAN, Capt. D.
PALMISANO, Dr. A.

ODS

BERTHIAUME, Mr. H.
BESHAI, Ms. .
BRESLIN, Mr. D.
BUSH, Mr. T.
CYR, Ms. C.
*JANSSEN, Mr. A.
LECARPENTIER, Mr. C
MOREHOUSE, Mr. E. T.
MULLENHARD, Mr. P

MUNITIONS

ANSELL, Mr. E.
BOULAY, Capt. R.
FLECK, Mr.W.
GOLDBERG, Mr. R.
*GRUNERT, Mr. C.
LEWIS, Mr. R.
SACHAR, Mr. T.
SEMEIT, Mr. C.
WILKINSON, Maj. A.

VOC

BERTHIAUME, Mr. H.
BESHAI, Ms. J.
BOSSARD, Mr. R.
GAWENIS, Mr. Chuck
GOASDOUE, Mr. J.
HERRING, Mr. C.
HOFSTEDE, Mr. E.
JANSSEN, Mr. A.
MULLENHARD, Mr. P.
*REIMER, Dr. K.
*ROGERS, Ms. J.
ZANOWICZ, Mr. R.

*Contaminant Area Leader (or Co-Leader)

COATINGS

BESHAI, Ms. J.
BOWERS, Capt. C.
BOSSARD, Mr. R.
GOASDOUE, Mr. J.
HOFSTEDE, Mr. E.
KINZIE, Mr. R.
*MARSHALL, Dr. G.
MONAHAN, Capt. D.
POK, Ms. M.
PULLEY, Mr. D.
RUDROFF, Mr. J.
*TUMARKIN, Dr. J.

SHIP WASTES

ALIG, Mr. C.
BOSSARD, Mr. R.
BRYCE, Mr. D.
*CLARK, Ms. S.
JANSSEN, Mr. A.
KOSS, Mr. L.
*LARBURU, Cdr. J.
LECARPENTIER, Mr. C.
McCAFFREE, RAdm. B. C. (Ret.)
OTTEN, Mr. C.
PALMISANO, Dr. A.
RODRIGUEZ, Mr. T.

PESTICIDES

FORDHAM, Mr. W.
*MARSHALL, Dr. G.
McKENNA, Lt. Col. R.

*Contaminant Area Leader (or Co-Leader)

PANEL 1 ON LONG-TERM SCIENTIFIC STUDIES

COMMISSION 1 SUR LES ETUDES SCIENTIFIQUES A LONG TERME

AC/243 (P.01)

List of Members / Liste des Membres

CHAIRMAN/PRESIDENT

WILLEMSEN, Ir. G. A.
TNO-Physics and Electronics Laboratory
TNO-FEL
P. O. Box 96864
2509 JG The Hague
The Netherlands

Tel: [31] (70) 326-4221
Fax: [31] (70) 328-0961
Email: willemsen@fel.tno.nl

VICE-CHAIRMAN/VICE-PRESIDENT

GARDNER, Dr. K. L.
Head, Defence Research Section
Defence Support Division
NATO Headquarters
1110 Brussels
Belgium

Tel: [32] (2) 728-4420
Tel2: [32] (2) 728-4111 ext. 4420
Fax: [32] (2) 728-4103
Telex: 23-867

SECRETARY/SECRETAIRE

STAMATOPOULOS, Mr. D.
Defence Research Section
Defence Support Division
NATO Headquarters
1110 Brussels
Belgium

Tel: [32] (2) 728-4286
Fax: [32] (2) 728-4103

(*) = Point of Contact

BELGIUM / BELGIQUE

VANDERHASTEN, Lt.Col. J. P. (*)
Etat-Major General
Division Materiel
Section Recherche et Developpement
(JSM R&D)
Quartier Reine Elisabeth
Rue d'Evere
1140 Bruxelles
Belgique

Tel: [32] (2) 701-6614
Tel2: IVSN 252-6614
Fax: [32] (2) 701-6620

CANADA

SCHMITKE, Mr. R.
Counsellor, Defence Research & Develop.
The Canadian Embassy
Sophialaan 7
P. O. Box 30820
2514 JP The Hague
The Netherlands

Tel: [31] (70) 361-4111
Fax: [31] (70) 356-1111

STREET, Dr. K.
Director, Intern. Research & Develpment
Department of National Defence
MGen George R. Pearkes Building
101 Colonel By Drive
Qttawa, Ontario
K1A OK2
Canada

Tel: [1] (613) 992-0725
Fax: [1] (613) 996-0038

(*) = Point of Contact

DENMARK / DANEMARK

KRARUP-HANSEN, Mr. N. (*)

Danish Defence Research Establishment	Tel:	[45] 3927-2233 ext.6020
Ryvangs Alle 1	Tel2:	[45] 3927-8888 + 6020
P. O. Box 2715	Fax:	[45] 3120-3315
DK-2100 Copenhagen		
Denmark	Telex:	22994 COMKBH DK

FRANCE

DESVERGNES, ICA P. (*)	Tel:	[33] (1) 4552-4650
DRET/SDR	Fax:	[33] (1) 4552-6520
00460 Armees		
France		

GERMANY / ALLEMAGNE

WENTHE, BDir. V. (*)

Federal Ministry of Defence	Tel:	[49] (228) 125751
Ru T I 4	Tel2:	[49] (228) 124219
Postfach 1328	Fax:	[49] (228) 126784
D-53003 Bonn 1		
Germany	Telex:	0886575

GREECE / GRECE

PAPASPIRIDAKOS, Capt. M. D. (*)	Tel:	[30] (1) 652-0668
Director HNGS/G5		
Holargos		
Athens		
Greece		

(*) = Point of Contact

NETHERLANDS / PAYS -BAS

BROEDERS, Ir. R.F.M.J. (*)
Ministry of Defence/DWOO
P. O. Box 20701
2500 ES, The Hague
The Netherlands

Tel: [31] (70) 318-7981
Fax: [31] (70) 318-8145
Telex: 31337

SPAIN / ESPAGNE

PEREIRA RUEDA, Cdr.Eng. M. (*)
Subdireccion General de Tecnologia E Investigacion
c/Arturo Soria, 289
28033 Madrid
Spain

Tel: [34] (1) 302-4743/44
Fax: [34] (1) 302-8047

UNITED KINGDOM / ROYAUME UNI

GRIMSHAW, Dr. J. (*)
R(C3)
MOD
Main Building, Room 1199
Whitehall
London SW1A 2HB
United Kingdom

Tel: [44] (71) 218-7134
Fax: [44] (71) 218-6481

RIDLER, Dr. T.
ADR(C) - Room 1152
MOD
Main Building
Whitehall
London SW1A 2HB
United Kingdom

Tel: [44] (71) 218-6898
Fax: [44] (71) 218-6481
Telex: 22241

(*) = Point of Contact

UNITED STATES / ETATS-UNIS

IAFRATE, Dr. J. (*)
Director
Army Research Office
Attention: AMXRO-D
P. O. Box 12211
4300 South Miami Blvd
Research Triangle Park
North Carolina 27709-2211
United States
Tel: [1] (919) 549-4201
Fax: [1] (919) 549-4348

HEIN, Mr. W .D.
US Army Research Office
4300 South Miami Blvd
P. O. Box 12211
Research Triangle Park
North Carolina 27709-2211
United States
Tel: [1] (919) 549-4228
Fax: [1] (959) 549-4348

SACLANT

NESBIT, Capt. K. G.
C-45
SACLANT
Branch Head, Long Term Armaments Plan.
Norfolk, VA 23551-2490
United States
Tel: [1] (804) 445-3477
Tel2: IVSN 555-3477
Fax: [1] (804) 445-3242

SIMPSON, Mr. R. A.
N-574
SACLANT
Analysis/Operations Research Branch
Norfolk, VA 23551-2490
United States
Tel: [1] (804) 445-3385
Tel2: IVSN: 555-3385
Fax: [1] (804) 445-3242

(*) = Point of Contact

SHAPE

GUTTMAN, Col. P. M. (*)
SHAPE
Command Group
7010 SHAPE
Belgium

Tel: [32] (65) 447111 Ext. 5312
Fax: [32] (65) 443545

IMS / EMI

FRANKS, Lt. Col. T.
NATO Headquarters
IMS
A&S Division
Staff Officer, Research & Technology
1110 Brussels

Tel: [32] (2) 728-5360
Fax: [32] (2) 728-4117

DRG DOCUMENT CENTRES

NATO does not hold stocks of DRG publications for general distribution. NATO initiates distribution of all DRG documents from its Central Registry. Nations then send the documents through their national NATO registries, sub-registries, and control points. One may sometimes obtain additional copies from these registries. The DRG Document Centres listed below can supply copies of previously issued technical DRG publications upon request.

BELGIUM
EGM-JSRL
Quartier Reine Elisabeth
Rue d'Evere,
1140 Bruxelles
Tel:(02)243 3163, Fax:(02)243 3655

CANADA
Directorate of Scientific Information Services
National Defence Headquarters
MGen. George R. Pearkes Building
Ottawa, Ontario, K1A OK2
Tel:(613)992-2263, Fax:(613)996-0392

DENMARK
Forsvarets Forskningstjeneste
Ryvangs Alle 1
2100 København Ø
Tel:3927 8888 + 5660,
Fax:3543 1086

FRANCE
CEDOCAR
00460 Armées
Tel:(1)4552 4500, Fax:(1)4552 4574

GERMANY
DOKFIZBw
Friedrich-Ebert-Allee 34
5300 Bonn 1
Tel: (0228)233091, Fax:(0228)125357

GREECE
National Defence Headquarters
R+T Section (D3)
15561 Holargos, Athens
Tel: (01)64 29 008

ITALY
MOD Italy
SEGREDIFESA IV Reparto PF.RS
Via XX Settembre, 123/A
00100 Roma
Tel:(06)735 3339, Fax:(06)481 4264

THE NETHERLANDS
KMA Bibliotheek
Postbus 90154
4800 RG Breda
MPC 71 A
Tel:(076)527-4911, Fax:(076)527-4252

NORWAY
Norwegian Defence Research Establishment
Central Registry
P.O. Box 25
2007 Kjeller
Tel:(06)80 71 41 Fax:(06)80 71 15

PORTUGAL
Direcção-General de Armamento
Ministério da Defesa Nacional
Avenida da Ilha da Madeira
1499 Lisboa
Tel:(01)610001 ext.4425, Fax:(01)611970

SPAIN
DGAM
C/ Arturo Soria 289
28033 Madrid
Tel:(91)2020640, Fax (91)2028047

TURKEY
Genelkurmay,Genel Plân Prensipler
Savunma Arastırma Daire Başkanlıgı
Ankara
Tel:(4)1176100 ext.1684, Fax:(4)11763386

UNITED KINGDOM
DRIC.
Kentigern House, 65 Brown Street
Glasgow G2 8EX
Tel:(041)224 2435, Fax:(041)224 2145

UNITED STATES
DTIC
Cameron Station
Alexandria, VA 22304-6145
Tel:(202)274-7633, Fax:(202)274-5280

DEFENCE RESEARCH SECTION
NATO HEADQUARTERS
B 1110 BRUSSELS
BELGIUM
Telephone [32](2)707 4285 - Telefax [32](2)707 4103
(not a DRG Document Distribution Centre)